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THE CHEMICAL CONTROL OF THE TOMATO HORNWORM ON TOBACCO IN ONTARIO[1]

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The tomato hornworm, *Protoparce quinquemaculata* (Haw.), is an important insect enemy of tobacco in Ontario. The larvae feed voraciously on the foliage, and most growers are obliged to spray or dust every year to avoid serious losses. Considerable work has been done on the chemical control of the tomato hornworm on tobacco, the results of which may be of interest to those concerned with tobacco culture. Starting in 1938, experiments have been undertaken by the Dominion Entomological Laboratory, Chatham, Ontario, not only to improve hornworm control but also to find suitable insecticides which would not leave poisonous or otherwise objectionable residues on treated plants. As new insecticides and new methods of control are being developed it seems advisable to bring together the results of these earlier experiments, both for a matter of record and comparison of results.

HISTORY

The first record of hornworm attacking tobacco in Ontario is contained in the evidence taken by the Ontario Agricultural Commission in 1880. J. P. McKinlay of Kent County is quoted as saying, "The tobacco worm was troublesome to the leaves sometimes; and, if it was left alone, would devour a considerable portion of the crop" (1).

Between 1880 and the present, the insect is mentioned irregularly in the reports of the Dominion Entomologist (4), (5), in the Annual Reports of the Entomological Society of Ontario (2), in the Canadian Insect Pest Review (8) and in the Reports of the Dominion Experimental Station, Harrow, Ontario (6), (7). These publications indicate that irregular peaks of high population occurred in the years 1892, 1901, 1919, 1921, 1924, 1931, 1939 and 1945.

Prior to 1920, arsenical sprays were used in years of severe hornworm infestations to replace the older method of hand-picking. Subsequently, the use of acid lead arsenate became general as a regular annual treatment and it then became necessary to consider the poisonous residues of lead and arsenic. Growers were urged to practise other control measures, which

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included fall ploughing, the destruction of larvae in curing barns and on second-growth tobacco, and the trapping of adults. None of these was considered sufficiently effective to warrant the effort and none was generally accepted. The only control considered practical, then as now, is an application of insecticide to the leaves. This is indicated in a recent survey conducted by a large tobacco company in Ontario which disclosed that about 95 per cent of the growers of flue-cured tobacco and about 50 per cent of the burley growers apply insecticides annually.

FIELD EXPERIMENTS

In 1938, a series of field experiments was begun by the staff of the Dominion Entomological Laboratory at Chatham, Ontario, under the direction of G. M. Stirrett. Two of these experiments were conducted at the Norwood farm, Lynedock, Ontario; one at the de Meyere farm, Thamesville, Ontario; and the remainder at the Dominion Experimental Substation, Delhi, Ontario.

In discussing these experiments the term "commercial control" is occasionally used. The term is elastic and differs in meaning when applied to various crops and indeed on the same crop under varying circumstances. In years of low or average hornworm populations, 70 per cent reduction of the larval population on tobacco may be considered "commercially" adequate, but during outbreaks, control would need to approach or exceed 95 per cent to protect the crop adequately. Control of the larvae must, as a consequence, keep severe leaf damage to 3 per cent or less. Observations by competent growers and entomologists have shown that fields with more than 3 per cent severe damage are not considered a commercial success.

The effects of varying strengths of an insecticide and the effects of different insecticides were evaluated by determining the relationship between the number of larvae surviving under the different conditions of treatment and in some cases also by recording the percentage of injured leaves. In the tables given, the figure "percentage control" is based on the population in the untreated check plots.

As hornworm moths continue to oviposit and the eggs continue to hatch after insecticidal treatments, more than one count of the larval population was usually undertaken. In this way, information was obtained on the residual effect of the insecticide on the surviving or newly hatched population. In no case was the evaluation carried to the end of the growing season to determine the full residual effect.

Prior to applying any of the treatments, eggs and larvae were counted on a large sample of plants to determine the proper time to treat the plots. When a total of 5 eggs and larvae were seen on 100 plants it was considered time to begin application. Post-treatment larval counts in the various tests were based on from 5 per cent to 40 per cent of the plants in the experimental areas, depending on the particular experiment.

As a suitable gauge was not available on the sprayers used, records of the pressures at which sprays were applied were not kept, the dosage being based on the total amount per acre and the coverage.

Results of 1938 Experiments

During the 1938 season, tests were made of possible substitutes for lead arsenate, using barium fluosilicate, synthetic cryolite, and calcium arsenate. Treatments, and an untreated control, were randomized in plots and replicated 6 times. Each plot was composed of 11 rows 34 feet long and had an area of about one thirty-fifth of an acre. Treatments were applied on July 26 by means of a wheelbarrow hand-operated sprayer with a capacity of 15 gallons. To measure the effectiveness of the sprays, larvae were counted on 10 per cent of the plants selected at random on July 29 and August 4. The results of the test are given in Table 1.

TABLE 1.—THE RESULTS OF CHEMICAL CONTROL EXPERIMENTS CONDUCTED FOR THE CONTROL OF HORNWORM ON FLUE-CURED TOBACCO PLOTS AT THE DOMINION EXPERIMENTAL SUBSTATION, DELHI, ONTARIO, JULY 26 TO AUGUST 4, 1938

Treatment and rate per acre applied July 26	Number of larvae per treatment		Percentage control vs check	
	July 29	August 4	July 29	August 4
Lead arsenate, 1[illegible] lb.	10	6	89	74
Cryolite, 13 lb.	38	74	58	27
Calcium arsenate, 6 lb.	5[illegible]	81	43	2[illegible]
Barium fluosilicate, 13 lb.	82	90	8	11
Untreated check		101	—	—

Table 1 shows that under the conditions of this experiment synthetic cryolite was the best of the substitutes but was not so effective as lead arsenate when both were applied at the rate of 13 pounds per acre. Calcium arsenate and barium fluosilicate resulted in inferior controls at the rates tested.

Results of 1939 Experiments

In 1939, lead arsenate was applied as early, late, and combined early and late sprays. The chief object was to determine if the general practice of applying more than one spray was actually necessary. The term "early" as used in connection with this and a subsequent experiment means as soon as 5 eggs or larvae were seen on 100 random plants; "late" means 1 or 2 weeks thereafter.

Plots of one thirty-fifth of an acre were again used and each treatment was replicated 6 times. Larvae were counted on 10 per cent of the plants on July 28, 14 days after the "early" application and 2 days after the "late" application. The high rate of application in this test was the result of a faulty wheelbarrow sprayer which delivered the spray material at the heavy volume of 150 gallons per acre.

Table 2 indicates that in this experiment an early spray of lead arsenate at the rate of 18.5 pounds per acre was as effective as the combined early and late sprays of 18.5 pounds each; also that a late spray of 18.5 pounds was almost as effective as a combined early and late treatment of 7.4 pounds.

TABLE 2.—THE RESULTS ON JULY 28 OF APPLYING "EARLY" AND "LATE" LEAD ARSENATE SPRAYS, AT VARYING RATES FOR CONTROL OF HORNWORM ON FLUE-CURED TOBACCO PLOTS AT THE DOMINION EXPERIMENTAL SUBSTATION, DELHI, ONTARIO, ON JULY 14 (EARLY) AND JULY 26 (LATE), 1939

Treatment and rate per acre	Total pounds applied per acre	Number of larvae per treatment	Percentage control over check
Early, 18.5 lb.	18.5	7	97
Early and late, 18.5 lb.	37	8	97
Early and late, 7.4 lb.	14.8	19	92
Late, 18.5 lb.	18.5	24	90
Early, 7.4 lb.	7.4	35	85
Late, 7.4 lb.	7.4	64	72
Untreated check	0	229	—

In view of the infestations, all treatments were considered commercially successful except the last 7.4 pounds of lead arsenate per acre applied as a single, late spray.

Tests were also carried out in 1939 using nicotine bentonite, lead arsenate, and synthetic cryolite. The same spray equipment and plot arrangement were employed as in the 1938 experiment. To evaluate the treatments, the larvae were counted on 10 per cent of the plants.

The data in Table 3 were interpreted by those conducting the experiment as showing that lead arsenate applied at the rate of 3½ pounds per acre and cryolite at the rate of 8 pounds per acre gave commercially adequate controls. The remaining treatments, cryolite at 6 pounds per acre and nicotine bentonite at 8 pounds per acre, were not considered satisfactory.

TABLE 3.—THE EFFECT ON THE HORNWORM POPULATION OF APPLYING VARIOUS SPRAY MATERIALS AT 40 GALLONS PER ACRE TO FLUE-CURED TOBACCO PLOTS AT THE DOMINION EXPERIMENTAL SUBSTATION, DELHI, ONTARIO, JULY 20 TO 25, 1939

Treatment	Pounds of poison applied per acre (July 20)	Number of larvae per treatment (July 25)	Percentage control over check
Arsenate of lead	3½	25	87.5
Synthetic cryolite	8	42	79.0
Synthetic cryolite	6	59	70.5
Nicotine bentonite	8	174	13.0
Untreated check	0	200	—

Results of 1940 Experiments

In 1940, early, late, and combined early and late lead arsenate sprays at various levels were again tested. Each treatment, as well as an untreated check, was randomized in plots of one thirty-fifth of an acre replicated 10 times. A 15-gallon wheelbarrow sprayer was again used. The effectiveness of the sprays was measured by counting hornworm larvae on 10 per cent of the plants on August 7, 14, and 22, respectively, and also by recording, on August 23, all leaves moderately or severely injured; data for both criteria are transformed in Table 4 into percentages. Severely injured leaves were entirely worthless; moderately injured leaves were very greatly reduced in value; exact figures are not available.

TABLE 4.—THE EFFECT OF "EARLY" (AUGUST 2) AND "LATE" (AUGUST 9) APPLICATIONS OF LEAD ARSENATE SPRAYS AT DIFFERENT STRENGTHS ON THE HORNWORM POPULATIONS AND LEAF INJURY ON TOBACCO PLOTS AT VARYING PERIODS AFTER TREATMENT AT THE DOMINION EXPERIMENTAL SUBSTATION, DELHI, ONTARIO, AUGUST 2 TO 23, 1940

Treatment and rate per acre	Percentage control over check			Percentage of leaves injured as of August 23	
	First count August 7	Second count August 14	Third count August 22	Moderately	Severely
Early, 12 lb. Late, 12 lb.	89	97	95	1	0
Early, 12 lb. Late, 5 lb.	84	90	93	2	1
Early, 12 lb.	89	87	88	2	1
Late, 12 lb.	Not sprayed	92	81	7	4
Early, 5 lb. Late, lb.	71	92	88	2	1
Early 5 lb. Late, 12 lb.	58	92	98	1	1
Late, 5 lb.	Not sprayed	73	79	9	7
Early, 5 lb.	58	72	56	6	4
No treatment	Nil	Nil	Nil	17	31

Table 4 indicates that with one exception treatments including early applications of lead arsenate resulted in excellent control of the larvae and hence less injury to the leaves. The exception, where 5 pounds of lead arsenate per acre were applied early, was apparently the result of an inadequate amount of poison. The improvement in control observed in the second larval count in this treatment may have occurred because the larvae had more time to ingest lethal amounts of lead arsenate.

Table 4 shows that a "late" spray of 5 pounds per acre apparently adequately replaced the lost residue of the "early" spray. If one bears in mind economy, reduction of poisonous residue on the leaves, and reduction of leaf injury these results indicate that the two treatments, 12 pounds "early", and 5 pounds "early" and 5 pounds "late", were the most practical of the series.

In 1940, an experiment was conducted to determine at what rate a single application of synthetic cryolite would achieve as good control as one treatment of lead arsenate at the rate of 6 pounds (in 40 gallons of water) per acre. A horse-drawn traction sprayer was used to gain experience in the control obtained with field equipment compared with previous work in which a hand-operated sprayer was employed.

The experimental area was 66 rows wide and 378 feet long. A total of 112 plots, 39 feet long and 4 rows wide, was laid out. The experiment involved 7 randomized treatments, replicated 16 times; these treatments were cryolite at 5 rates, lead arsenate at 6 pounds per acre, and no treatment as shown in Table 5.

TABLE 5.—A COMPARISON OF A SINGLE LEAD ARSENATE SPRAY AT 6 POUNDS PER ACRE WITH SYNTHETIC CRYOLITE SPRAYS AT 6 TO 36 POUNDS PER ACRE FOR THE CONTROL OF HORNWORMS AND LEAF INJURY ON TOBACCO AT THE DOMINION EXPERIMENTAL SUBSTATION, DELHI, ONTARIO, AUGUST 5 TO 23, 1940

Treatment and rate per acre; sprayed August 5	Percentage control over check		Percentage of leaves injured as of August 23	
	First count August 10	Second count August 23	Moderately	Severely
Cryolite, 36 lb.	82	81	2	1
Cryolite, 24 lb.	79	79	3	1
Arsenate of lead, 6 lb.	77	73	3	2
Cryolite 18 lb.	69	56	2	1
Cryolite, 12 lb.	67	58	3	2
Cryolite, 6 lb.	37	54	4	[illegible]
No treatment	Nil	Nil	8	6

In Table 5, it will be noted that cryolite gave fair control of hornworms and good protection of the leaves when used at 18 pounds or more per acre; lower rates were not considered satisfactory. The results with 6 pounds of lead arsenate, under the conditions of the experiment, were only fair.

A third experiment was undertaken in 1940 to compare lead arsenate and synthetic cryolite, each applied as sprays and dusts of different strengths. Randomized treatments were applied on August 8 to two

TABLE 6.—A COMPARISON OF SYNTHETIC CRYOLITE AND LEAD ARSENATE SPRAYS AND DUSTS FOR HORNWORM CONTROL. NORWOOD FARM, LYNEDOCK, ONTARIO, AUGUST 8 TO 23, 1940

Treatment and rate per acre; applied August 8	Percentage control over check		Percentage of leaves injured	
	August 13	August 23	Moderately	Severely
Method—horse-drawn hand sprayer				
Synthetic cryolite, 22 lb.	94	91	2	0
Lead arsenate, 2.5 lb.	82	89	5	1
Lead arsenate, 4.5 lb.	72	97	5	1
Synthetic cryolite, 5.5 lb.	79	86	4	1
Synthetic cryolite, 11 lb.	87	74	5	3
Method—horse-drawn power duster				
Lead arsenate, 17 lb.	93	91	4	1
Synthetic cryolite, 16.5 lb.	93	89	3	1
Synthetic cryolite, 29.[illegible] lb.	99	74	7	3
Lead arsenate 1, hydrated lime 8; 41.6* lb.	70	74	4	1
Cryolite, [illegible].1 lb.	63	34	13	6
Cryolite 1, celite [illegible]; 35.8† lb.	36	−6**	2	13
No treatment	Nil	Nil	15	14

* Five pounds only of this amount were arsenate of lead.
† Nine lb. only of this amount were cryolite.
** A negative sign preceding the percentage control figure indicates that the larval population exceeded that in the check plots.

blocks, each containing 12 plots. Those subjected to spraying were 4 rows wide and one-ninth of an acre in area, and the dusted plots were 6 rows wide and one-sixth of an acre in area. A horse-drawn hand-pumped sprayer and a horse-drawn power duster were used to apply the materials. The sprays were applied at the rate of approximately 40 gallons per acre.

Table 6 shows that a dust of lead arsenate at the rate of 17 pounds per acre gave very nearly as good results as the most effective spray. It is difficult to explain why sprays of lead arsenate at the rate of 4.5 pounds per acre, synthetic cryolite at the rate of 11 pounds per acre, and the dust of synthetic cryolite at the rate of 29.8 pounds per acre made such a relatively poor showing.

Synthetic cryolite dusts generally did not remain effective for so long a period as did lead arsenate dusts or the liquid sprays of either poison. The percentage reduction of larvae fell from 63 to 34 and from 99 to 74, respectively within 9 days when cryolite dusts were used at 6.1 and 29.8 pounds per acre. For some reason this loss of effectiveness was not nearly so marked when 16.5 pounds of cryolite were used. It will also be seen that sprays of both materials and dusts of lead arsenate in general either increased the percentage of control or dropped only slightly in effectiveness during the period of observation.

Results of 1947 Experiments

No further insecticidal tests were conducted on tobacco in the field until 1947, when sprays of the newer insecticides DDT, chlordane, benzene hexachloride, and ryania were compared with those of lead arsenate.

Thirty plots of one-third of an acre each were laid out on the de Meyere farm near Thamesville, Ontario. These plots were subjected to 10 randomized spray treatments, each replicated 3 times. The treatments were applied on August 8, at the rate of approximately 40 gallons per acre by means of a horse-drawn, manually operated 4-row sprayer with a capacity of 40 gallons.

TABLE 7.—A COMPARISON OF SPRAYS OF DDT, LEAD ARSENATE, RYANIA, CHLORDANE, AND BHC AT DIFFERENT STRENGTHS FOR THE CONTROL OF HORNWORMS ON TOBACCO AT THE DE MEYERE FARM, THAMESVILLE, ONTARIO, AUGUST 8 TO 15, 1947

Treatment applied August 8	Pounds of poison per acre	Number of larvae per treatment		Percentage control over check	
		August 12	August 15	August 12	August 15
DDT	1.3	2	1	99.5	99.7
DDT	2.2	6	3	98.6	99.1
DDT	0.72	15	4	96.4	98.8
Lead arsenate	4.7	28	13	93.4	95.9
Lead arsenate	2.2	119	47	72.1	95.1
Ryania	2.5	80	66	81.2	79.0
Chlordane	1.5	131	29	69.3	90.8
Chlordane	0.65	240	212	43.8	32.8
BHC	0.18*	436	294	−2.1	6.7
Untreated check	Nil	427	314	—	—

* This amount contained 6 per cent gamma isomer.

Data in Table 7 show that DDT applied as a 50 per cent wettable powder in water was the best insecticide at any of the rates tried. Applications of 2.2, 1.3, and 0.72 pounds of actual DDT per acre, all gave excellent control. The results with chlordane were variable but the 1.5 pound rate gave fair control. Ryania showed some promise but, in this instance, was slightly below "commercial control". Benzene hexachloride, at the strength applied, was disappointing. It should be noted that lead arsenate continued to give good commercial control and was second only to DDT in effectiveness.

Results of 1948 Experiment

In 1948, an experiment was conducted at the Dominion Experimental Substation, Delhi, Ontario, to determine if a single application of DDT dust was practical and adequate for the control of the hornworm on tobacco. Plots of one-tenth of an acre were dusted on July 22 with the following preparations:

5 per cent DDT,
3 per cent DDT,
3.2 per cent lead arsenate.

These preparations were applied on July 22 at the rate of 30 pounds per acre by means of a motor-driven wheelbarrow duster. Each treatment was replicated 3 times in a random design.

Larval counts were taken on July 27, August 4, August 11, and August 27, i.e. 5, 13, 20, and 26 days after treatment. Each count was based on 200 plants or nearly 40 per cent of the total. These were selected at random in each plot and examined for larvae. Outside rows and the ends of rows were avoided to prevent interference from adjacent treatments.

Table 8 shows that both 5 per cent and 3 per cent dusts of DDT gave commercially adequate controls of 72.5 per cent and 70.5 per cent, respectively. The lead arsenate dust was worthless in this experiment.

TABLE 8.—THE RESULTS OF EXPERIMENTAL TRIALS WITH DDT AND LEAD ARSENATE DUSTS FOR HORNWORM CONTROL ON TOBACCO PLOTS AT THE DOMINION EXPERIMENTAL SUBSTATION, DELHI, ONTARIO, JULY 22 TO AUGUST 27, 1948

Treatment applied July 22	Number of larvae per treatment				Percentage control over check				Seasonal average per cent control
	July 27	Aug. 4	Aug. 11	Aug. 27	July 27	Aug. 4	Aug. 11	Aug. 27	
DDT, 5 per cent	6	1	36	31	66.7	92.9	67.6	63.1	72.5
DDT, 3 per cent	10	0	48	16	44.4	100.0	56.8	80.9	70.5
Lead arsenate, 3.2 per cent	17	1	139	97	5.6	21.5	−25.2	−15.4	−3.3
Untreated check	18	14	111	84	0	0	0	0	—

DISCUSSION

Study of these tables indicates that where arsenate of lead was used a thoroughly applied early spray was as effective as two sprays applied early and late, provided the total amount of poison applied per acre was com-

parable. The large amount of leaf injury suffered in plots receiving a single "late" treatment ruled out the advisability of relying on late application for adequate control.

As a result of these experiments, it is now recommended that where synthetic cryolite is used it should be applied at a rate of 18 to 20 pounds per acre. Because of the higher cost of cryolite, it has not been widely employed by growers.

Of all the insecticides tested, DDT was by far the most effective, even at the comparatively low concentration of 0.72 pounds per acre; moreover, DDT does not leave so much undesirable residue on the foliage as lead arsenate or cryolite.

In these experiments, sprays were generally more effective than dusts, but experienced tobacco growers who have used DDT dusts have expressed complete satisfaction with the results.

No injury which could be attributed to the insecticides was seen on the tobacco leaves in any of the experiments.

In conclusion, it is felt that DDT, as a control for hornworm, fulfils many of the requirements of an ideal insecticide and that it has solved, for the time being at least, the problem of finding an acceptable insecticide to control the tomato hornworm on tobacco.

SUMMARY

A brief history of the tomato hornworm on tobacco and its control in Ontario is given.

Field experiments on the control of the tomato hornworm on tobacco by means of chemicals, conducted during 1938, 1939, 1940, 1947, and 1948 by the staff of the Dominion Entomological Laboratory at Chatham, Ontario, are outlined. All tests were run on flue-cured tobacco, chiefly at the Dominion Experimental Substation, Delhi, Ontario.

The insecticides tested included ryania, nicotine bentonite, synthetic cryolite, barium fluosilicate, calcium arsenate, lead arsenate, chlordane, benzene hexachloride, and DDT. Of these, DDT was by far the most effective, even at concentrations as low as 0.72 pounds of actual DDT per acre, and the prediction is made that this material will probably replace other poisons now in use in Ontario.

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SOIL MOISTURE STUDIES

IV. INDIRECT DETERMINATION OF FIELD CAPACITY FOR MOISTURE[1]

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In a previous paper in this series (9), it was suggested that the field capacity of the soil for moisture could be used as a basis for supplemental classification of soils following a soil survey. This method has subsequently been used (10, 11, 12) to good effect in classifying soils with respect to moisture-holding capacity (as representing soil texture), and in correlating field capacity for moisture with other factors. In this subsequent work, the field capacity was determined by laboratory procedures, as outlined in the second paper of this series (8).

When the investigation noted above was undertaken, soil samples were collected 24 hours after irrigating, at a standard depth of 8 to 12 inches. These samples contained very little organic matter. The question arose, therefore, as to whether the results obtained could safely be applied to A horizons, containing organic matter in moderate amount. In an attempt to answer this question, it was decided to repeat the investigation, obtaining the samples from two depths representing different contents of organic matter. It was anticipated that the curves and equations obtained would also serve to check the results already reported (8). This present paper summarizes the results of the second investigation.

In view of the fact that the literature on this subject was covered in the second paper of this series (8), it will not be repeated in this paper.

PROCEDURE

A total of 54 locations were selected in irrigated orchards in the Okanagan Valley, in 1944 and 1945. A wide range of soil texture was represented. Soil samples were taken approximately 24 hours after completion of an irrigation. At each location, two samples were taken at a depth of 4 to 8 inches, and two at a depth of 10 to 14 inches. Each sample was taken with a sampling can 3 inches in diameter, 4 inches deep, and of known volume. The two samples from each depth were composited. Where gravel or stones were encountered, the samples were discarded; thus only one depth was represented at some locations.

In the laboratory, each composited soil sample was weighed, screened through a 3 mm. sieve, mixed thoroughly, and dried. Calculations were made on volume weight, field capacity for moisture in percentage dry weight, and field capacity in inches of water per foot of soil.

The wilting coefficients of most of the samples were determined by growing sunflowers in a portion of each sample in the greenhouse. The available moisture contents were determined by deducting the wilting coefficient figures from the field capacity figures.

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The moisture equivalents were determined with an International clinical centrifuge, using a modification of the procedure suggested by Goldbeck and Jackson (3). The centrifuge was run for 30 minutes at a speed sufficient to produce a centrifugal force of 200 atmospheres, which gave results very close to those obtained in a standard moisture equivalent centrifuge at 1000 atmospheres. This apparent discrepancy can be attributed primarily to differences in packing of the soil and to the use of a different type of centrifuge head.

Other measurements made on the soil samples included the settling volume, mechanical analysis, and organic matter content. The settling volume was determined by the procedure described by Wilcox and Spilsbury (8), the mechanical analysis by the Bouyoucos hydrometer procedure (1), and the organic matter content by the hydrogen peroxide method of Robinson (5) as modified by Wilcox and Walker (12).

Correlations were determined between field data and laboratory measurements, and between different types of laboratory determinations.

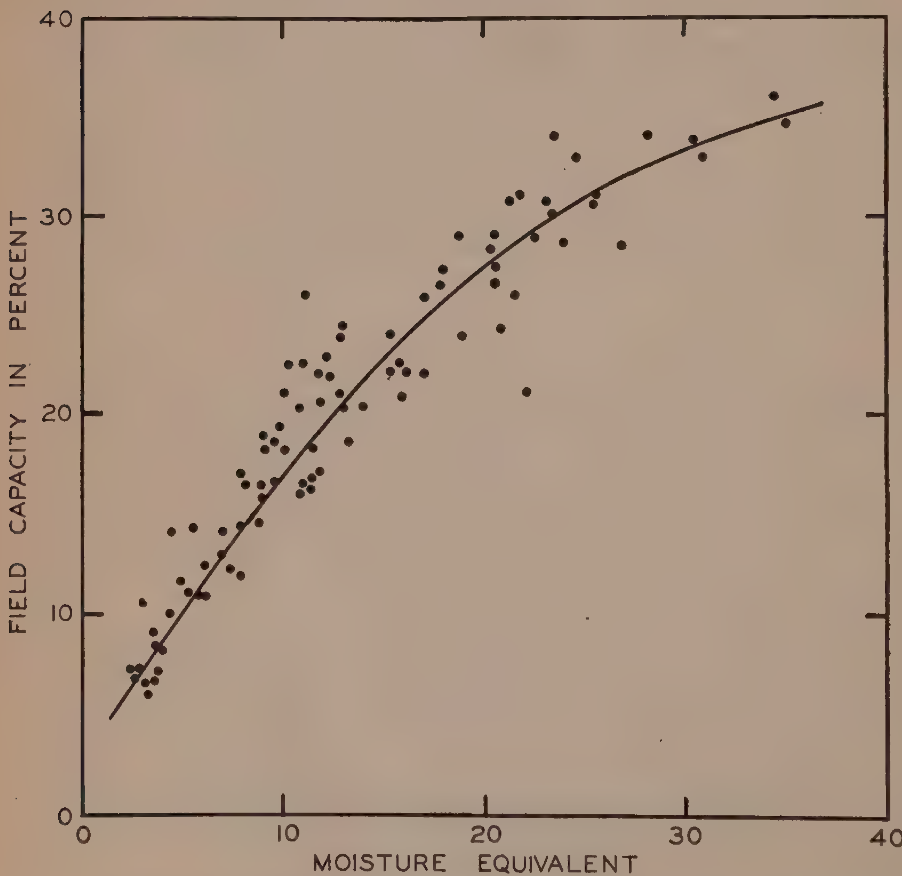

FIGURE 1. Scatter diagram of field capacity in per cent charted against moisture equivalent. The curve shown has the equation $y = 2.29 + 1.66x - 0.0207x^2$, in which y = field capacity and x = moisture equivalent.

Both straight line equations and second degree polynomial equations (6) were calculated for determining the field capacity, wilting coefficient and available moisture content from the various laboratory measurements. Since previous work (8) had indicated that correlations with silt content gave low and unreliable coefficients, no calculations involving silt content were made. The standard error was determined for each equation, and was expressed in percentage of the mean of the function being determined.

RESULTS

The more pertinent data obtained in the course of this investigation are summarized in Table 4. Figures for available moisture have been omitted from the table, but these can readily be calculated by deducting the wilting coefficient figures from the field capacity figures.

Effects of Depth of Sampling

It was anticipated that the higher organic matter contents in the 6-inch (i.e. 4-8 inch) samples would be accompanied by higher field capacities, in comparison with the 12-inch (i.e. 10-14 inch) samples. However, this did not prove to be true. More often than not, the field capacity was higher in the 12-inch samples than in the 6-inch samples. Typical results are presented in Table 1.

TABLE 1.—COMPARISON OF 6-INCH AND 12-INCH SAMPLES

Sample No.	Average depth	Organic matter	Field capacity	Moisture equivalent	Colloid
	in	%	%	%	%
2a	6	0.75	11.8	7.8	11.3
2b	12	0.50	16.6	9.6	13.9
6a	6	0.77	21.9	12.4	18.9
6b	12	0.34	22.8	12.2	17.4
19a	6	1.50	34.0	23.6	44.6
19b	12	0.67	32.8	24.6	45.2
23a	6	1.13	20.8	16.0	38.1
23b	12	0.70	28.5	26.8	57.5
34a	6	0.27	6.6	3.4	6.9
34b	12	0.03	7.3	3.0	8.9
35a	6	0.24	9.1	3.6	8.4
35b	12	0.02	7.3	2.8	6.8
53a	6	0.34	33.8	30.4	76.6
53b	12	0.02	34.7	35.0	83.8

In spite of higher contents of organic matter in the 6-inch samples, the colloid content was usually higher in the 12-inch samples. The reason for this has not been ascertained. It is suspected to be due to movement of the finer soil particles from the surface soil downward into the subsoil, especially in the sandy soils. The moisture equivalent showed a close correlation with both the field capacity and the colloid content, as indicated in Table 1. It might be noted that the organic matter contents were all comparatively low.

TABLE 2.—COEFFICIENTS OF CORRELATION

	Percentage sand	Percentage clay	Percentage colloid	Settling volume	Moisture equivalent
Field capacity, in per cent	−0.92	+0.82	+0.86	+0.91	+0.93
Wilting coefficient, in per cent	−0.88	+0.85	+0.91	+0.94	+0.94
Available moisture, in per cent	−0.91	+0.76	+0.82	+0.89	+0.89
Field capacity, in inches	−0.89	+0.76	+0.79	+0.88	+0.89
Wilting coefficient, in inches	−0.92	+0.82	+0.87	+0.92	+0.92
Available moisture, in inches	−0.85	+0.70	+0.72	+0.82	+0.83
Volume weight	+0.85	−0.80	−0.81	−0.86	−0.87
Settling volume	−0.95	+0.89	+0.94	—	+0.88
Moisture equivalent	−0.94	+0.93	+0.96	+0.88	—

These results give no indication of any distinct effect of the organic matter content on the relations between field capacity on the one hand and moisture equivalent or colloid content on the other hand; at least, at the low organic matter contents encountered in this investigation. Accordingly, all of the soil samples were grouped together in calculating the correlations and equations reported below.

Correlations

Those correlations of special interest are presented in Table 2. They are all "highly significant", with odds greater than 99 : 1. On the whole, the coefficients listed are similar in value to those reported previously (8). A new feature is the column of correlations with moisture equivalent. These give coefficients almost the same as for those with settling volume. It will be noted that the correlations involving laboratory measurements only (such as between moisture equivalent and percentage colloid) tend to have distinctly higher coefficients than those including one field measurement (such as available moisture in inches and percentage colloid).

Equations

One of the major purposes of this investigation was to assess the accuracy of different laboratory methods of determining field capacity. To accomplish this, it was necessary to calculate the equations that could be used for determining field capacity from each of the laboratory determinations. This was done in two ways:

(a) on the basis of the equation

$$y = a + bx,$$

(b) on the basis of the equation

$$y = a + bx + cx^2$$

In these equations,

y = the function (e.g. field capacity in per cent).

x = the factor (e.g. moisture equivalent).

a, b, c = constants.

The first equation assumes a straight-line trend between the two values, the second a curved trend of the second-degree polynomial type. In a previous investigation (8), it was found that nothing was to be gained by using more than one factor in each equation. In this investigation, accordingly, only one factor was used at a time in making the calculations.

In addition to field capacity, equations have also been calculated involving wilting coefficient and available moisture. In almost every case, the curve equations were found to fit the distributions more accurately than the straight-line equations, and to give lower standard errors of estimate. In comparing the laboratory methods, therefore, it will be considered sufficient to do so on the basis of standard errors using the curve equations only. Such a comparison is presented in Table 3.

In three cases, the errors involved in using the straight-line equations were about the same as those from the curves. These were as follows:

Wilting coefficient in per cent, from moisture equivalent (18.5 per cent error)
Available moisture in per cent, from settling volume (17.3 per cent error)
Wilting coefficient in inches, from settling volume (17.1 per cent error).

The selection of a laboratory procedure to use in estimating field capacity, wilting coefficient or available moisture will depend not only on the percentage error involved, but also on the type of curve obtained and the ease of making the laboratory determinations. The closer the curve is to a straight line, the more readily can it be used for transposing values

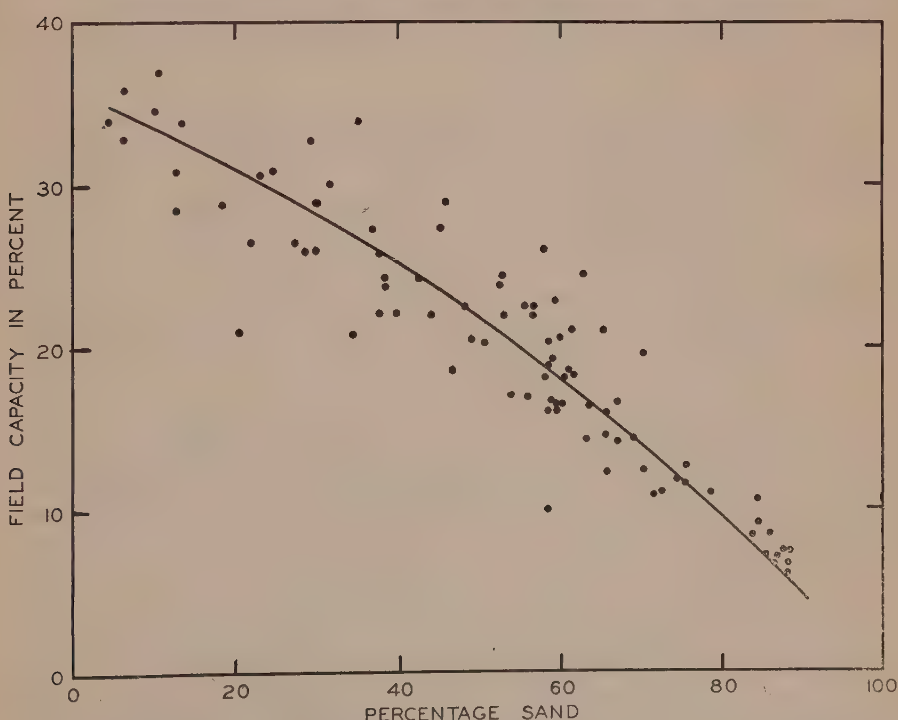

FIGURE 2. Scatter diagram of field capacity in per cent charted against percentage sand. The curve shown has the equation $y = 35.76 - 0.200x - 0.00158x^2$, in which y = field capacity and x = percentage sand.

TABLE 3.—STANDARD ERRORS OF ESTIMATE, IN PERCENTAGE OF THE MEAN OF THE FUNCTION

Function being determined	Factor used in determination: Percentage sand	Percentage clay	Percentage colloid	Settling volume	Moisture equivalent
Field capacity, in per cent	9.7	17.4	12.7	13.3	10.9
Wilting coefficient, in per cent	22.6	22.8	19.6	20.6	18.7
Available moisture, in per cent	13.3	20.3	17.4	17.5	11.8
Field capacity, in inches	10.6	16.6	14.0	15.0	13.3
Wilting coefficient, in inches	15.9	18.2	16.6	16.2	15.3
Available moisture, in inches	12.5	19.6	16.9	18.2	14.2

throughout the range encountered. Taking both percentage error and type of curve into account, the most satisfactory of the equations for routine use can be listed in order of preference as follows:

Field capacity in per cent:

(1) From moisture equivalent, $y = 2.29 + 1.66x - 0.0207x^2$. See Figure 1.
(2) From percentage sand, $y = 35.76 - 0.200x - 0.00158x^2$. See Figure 2, and compare with Figure 3.
(3) From settling volume, $y = -41.95 + 1.89x - 0.01019x^2$.

Wilting coefficient in per cent:

(1) From moisture equivalent, $y = 0.92 + 0.317x$. See Figure 4.
(2) From percentage colloid, $y = 0.82 + 0.186x - 0.000762x^2$.
(3) From settling volume, $y = -10.97 + 0.399x - 0.000865x^2$.

Available moisture in per cent:

(1) From moisture equivalent, $y = 0.89 + 1.494x - 0.0244x^2$. See Figure 5.
(2) From percentage sand, $y = 25.74 - 0.131x - 0.00127x^2$.

Field capacity in inches per foot of soil:

(1) From percentage sand, $y = 5.326 - 0.0205x - 0.000313x^2$.
(2) From moisture equivalent, $y = 1.12 + 0.23x - 0.00329x^2$.
(3) From percentage colloid, $y = 1.04 + 0.120x - 0.00090x^2$.

Wilting coefficient in inches per foot of soil:

(1) From moisture equivalent, $y = 0.13 + 0.0654x - 0.000519x^2$.
(2) From percentage sand, $y = 1.635 - 0.0117x - 0.0000539x^2$.

Available moisture in inches per foot of soil:

(1) From percentage sand, $y = 3.85 - 0.0138x - 0.000207x^2$.
(2) From moisture equivalent, $y = 0.13 + 0.279x - 0.00572x^2$.

In each of these equations, y represents the function and x represents the factor as noted above. The first equation, for example, could have been written as follows:

$$\text{Field capacity in per cent} = 2.29 + 1.66\,(\text{moisture equivalent}) - 0.0207\,(\text{moisture equivalent})^2.$$

The moisture equivalent appears, from this investigation, to be preferable to either the settling volume or mechanical analysis as an indirect method of determining the field capacity. Where a mechanical analysis has already been made, however—such, for example, as in the course of a soil survey—the data obtained can readily be used for estimating the field capacity.

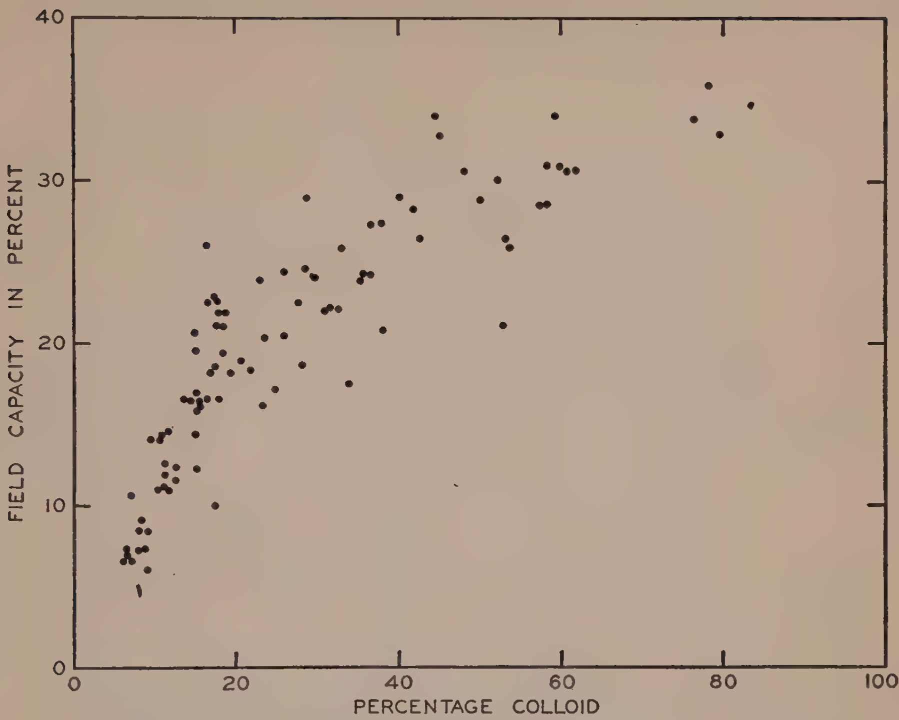

FIGURE 3. Scatter diagram of field capacity in per cent charted against percentage colloid.

A useful equation is that calculated for use in determining the field capacity in inches of water per foot of soil from the field capacity in per cent:

$$y = -0.040 + 0.214x - 0.00197x^2.$$

The use of this equation obviates the necessity of determining the volume weight of the soil in situ. The standard error of estimate was only 6.2 per cent of the mean, which is quite low for equations based on field determinations.

Relation Between Soil Texture and Available Moisture

Soil texture has been measured directly by mechanical analysis, and indirectly by settling volume and moisture equivalent determinations. The figures obtained from the mechanical analysis for percentages of sand, silt, clay and colloid all contribute to our knowledge of the texture of the soil. No one of these figures, however, gives the full story by itself.

It can be seen from the correlations noted above, that no matter how the texture was measured, there were strong tendencies for both the field capacity and the wilting coefficient to increase as the soil particles became finer. The question arises as to whether the difference between the field capacity and the wilting coefficient (i.e. the available moisture) should increase in similar manner. The strong positive correlations between available moisture and those measurements representing texture indicate

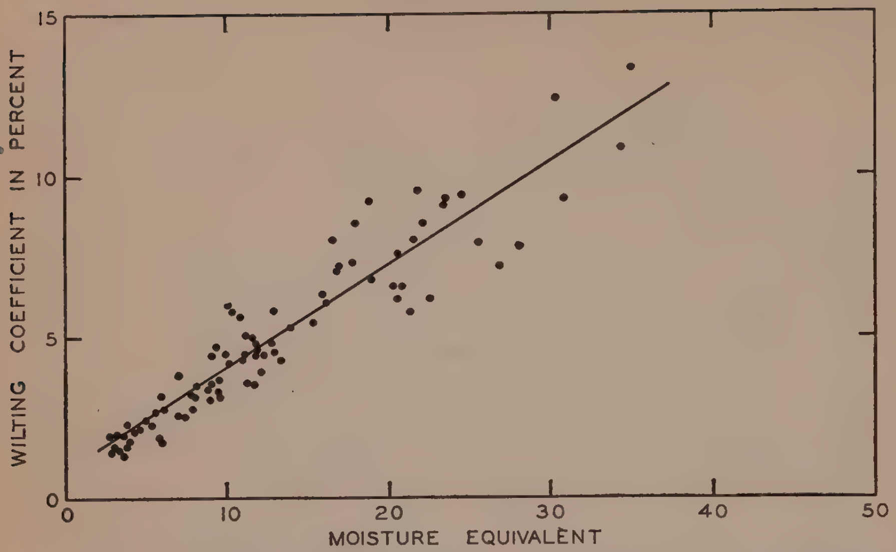

FIGURE 4. Scatter diagram of wilting coefficient in per cent charted against moisture equivalent. The curve shown has the equation $y = 0.92 + 0.317x$, in which y = wilting coefficient and x = moisture equivalent.

that it does. An examination of the various charts, however, reveals a general tendency for the available moisture to increase to a maximum and then decrease as the soil becomes still heavier. From the equations for the curves, the available moisture in per cent was found to be at a maximum at the following values:

Maximum of 25.7 when per cent sand = 0.
Maximum of 23.6 when per cent clay = 48.9.
Maximum of 23.4 when per cent colloid = 69.3.
Maximum of 23.7 when moisture equivalent = 30.0.

The available moisture in inches was at a maximum at the following values:

Maximum of 3.85 when per cent sand = 0.
Maximum of 3.43 when per cent clay = 35.2.
Maximum of 3.40 when per cent colloid = 51.3.
Maximum of 3.54 when moisture equivalent = 24.4.

Judging by the data from per cent clay, per cent colloid and moisture equivalent, the available moisture content of the soil does not increase indefinitely as the soil particles decrease in size. The maximum available moisture in per cent was at a clay content of about 50 per cent or a colloid content of about 70 per cent; and the maximum available moisture in inches of water was at a clay content of about 35 per cent or a colloid content of about 50 per cent. Of these four figures, the latter two are more applicable to field conditions, as the actual quantity of water available for plant use is measured in volume rather than in per cent. According to this, then, very heavy soils contain no higher content of available moisture than do moderately heavy soils with a clay content of about 35 per cent. This confirms a similar finding reported in 1941 (8).

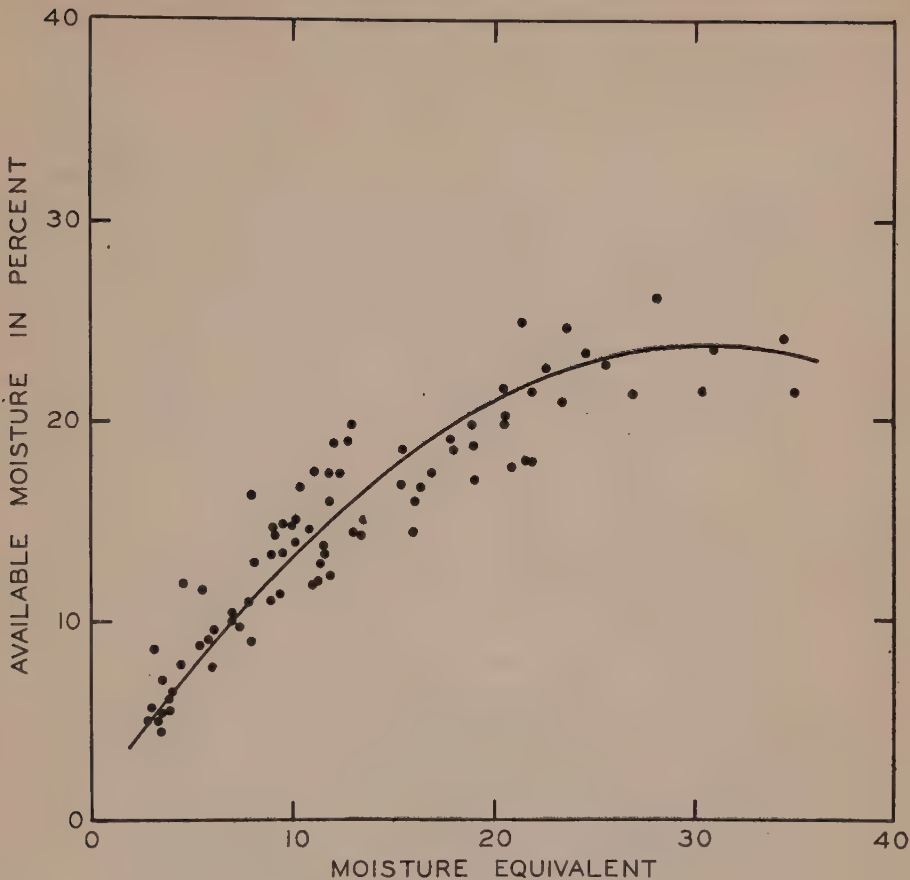

FIGURE 5. Scatter diagram of available moisture in per cent charted against moisture equivalent. The curve shown has the equation $y = 0.89 + 1.494x - 0.0244x^2$, in which y = available moisture and x = moisture equivalent.

The curves of available moisture plotted against per cent sand did not conform to those plotted against the other laboratory measurements. The available moisture content increased as the per cent sand decreased, right down to a sand content of zero. This was true whether the available moisture was expressed in per cent or in inches. This discrepancy between the sand curves on the one hand and the clay and colloid curves on the other hand appears to be due to two causes: *first*, the unpredictable effects of the silt content; and *second*, the fact that when the sand content approached zero, the soil could often be considered only "moderately heavy". A soil containing 35 per cent clay, 60 per cent silt and 5 per cent sand, i.e. a "silty clay soil", would be considered rather heavy; but it could be much heavier still with very little difference in the sand content.

Comparison of Field Data and Laboratory Data

In order to study laboratory methods of determining the moisture-holding capacity of the soil under field conditions, it has been considered necessary to use samples actually collected in the field at or near the

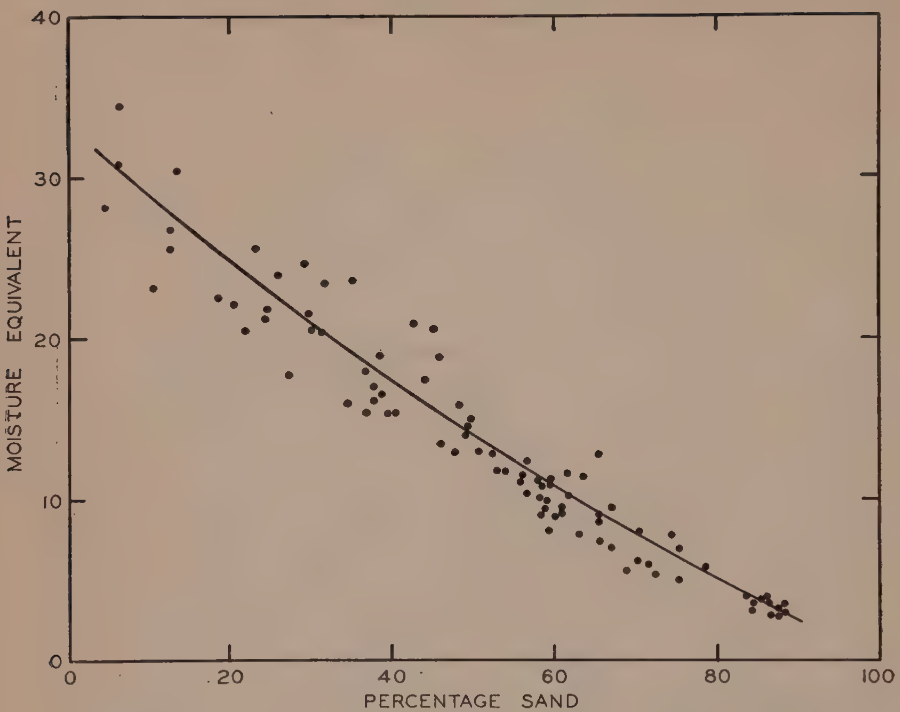

FIGURE 6. Scatter diagram of moisture equivalent charted against percentage sand. The curve shown has the equation $y = 33.35 - 0.447x + 0.00154x^2$, in which y = moisture equivalent and x = percentage sand.

moisture-holding capacity. It is recognized that the moisture content in the field is affected by many factors not operative in the laboratory, and is therefore more variable. The fact that field conditions are not simulated in the laboratory, however, constitutes a valid reason for obtaining the basic data right in the field.

The question arises as to what extent factors other than texture that are operative in the field affect the field capacity. In this present investigation, the best field and laboratory data available for comparison are the field capacity and the moisture equivalent. An examination of Table 2 reveals the following comparisons of coefficients of correlation:

Between field capacity and per cent sand	− 0.92
Between moisture equivalent and per cent sand	− 0.94
Between field capacity and per cent clay	+ 0.82
Between moisture equivalent and per cent clay	+ 0.93
Between field capacity and per cent colloid	+ 0.86
Between moisture equivalent and per cent colloid	+ 0.96

The correlations with field capacity were surprisingly high. On the whole, however, the correlations with the moisture equivalent were higher still.

The value of a coefficient of correlation depends primarily on two factors—*first*, the direction of the line of trend; and *second*, the distribution of the values away from this line. An examination of the scatter diagrams indicates that in every case the points were more widely scattered in the

field capacity charts than in the moisture equivalent charts. By way of example, Figure 2 can be compared with Figure 6, and Figure 3 with Figure 7.

Some of the sources of variability encountered in determining the field capacity are as follows:

(1) Variations in time that it takes the excess water to drain into the subsoil. It usually takes much longer with a heavy soil than a light soil. Choice of 24 hours after irrigation does not allow complete drainage in many cases before sampling.

(2) Variations in rate of absorption of moisture by plant roots during the 24 hours.

(3) Variations in the subsoil below. As already reported (7) more water remains above either a clay pan or a gravel layer than above a uniform silt or fine sand.

Under field conditions, it is impossible to select any one time after wetting when soils of varying type and under varying cultural treatment can all be said to be at the moisture-holding capacity. The use of 24 hours is merely a compromise between rate of drainage and rate of root absorption. At greater depths than those used in this investigation (6 inches and 12 inches), it would appear advisable to increase the interval between irrigating and sampling to more than 24 hours.

Because of the effects of these various factors on the moisture-holding capacity under field conditions, there is a wide variation from location to location in the field capacity of soil samples apparently almost identical in textual characteristics. This raises considerably the calculated standard error of conversion from a laboratory determination to the field capacity. As noted in Table 3, the standard errors determined in this investigation were comparatively high. Such a situation is unavoidable.

It still holds true that the best method of determining the true field capacity at any location is to take samples periodically in the field following an irrigation. Not only is there a source of error in making the conversion from a laboratory determination to the field capacity, but no laboratory method can take into account the effects of the various factors encountered in the field. To determine accurately the field capacity at any one location, it is necessary to determine it right at that location.

If absolute accuracy in determining the field capacity for moisture is not considered essential, however, then the use of a laboratory procedure may not only be permissible but advisable. Of those methods tested in this investigation, the moisture equivalent appears to be the most reliable. Other investigators (2, 4) have already used the moisture equivalent for this purpose, and have expressed or converted the values obtained by means of curves.

The question has frequently arisen as to whether the moisture equivalent can safely be used to represent the field capacity without the use of a converting factor or equation. An examination of Figure 1 will indicate that this would be risky, as the line of trend between the two is a definite curve. It will also be noted that the curves obtained from per cent sand and per cent colloid charted against field capacity (Figures 2 and 3)

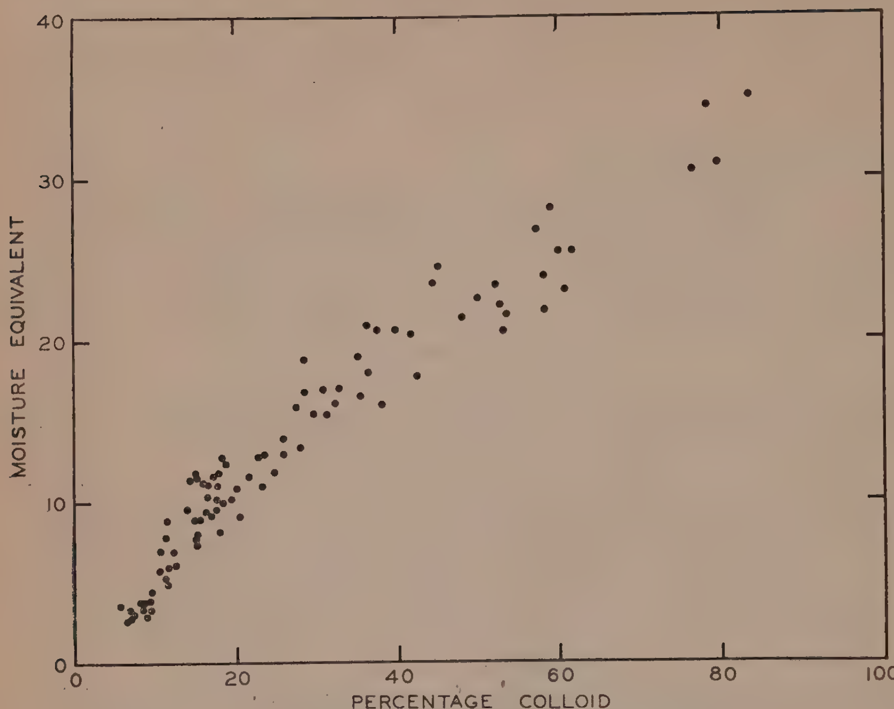

FIGURE 7. Scatter diagram of moisture equivalent charted against percentage colloid.

are somewhat different in shape from those of per cent sand and per cent colloid charted against moisture equivalent (Figures 6 and 7). If the moisture equivalent is to be used for estimating the field capacity, it appears safest to use the curve or its equation for transposing the values. It should be noted that the moisture equivalent was not determined in this investigation by the standard procedure, and that the curves obtained could not safely be used for standard moisture equivalent values without checking them first.

SUMMARY

Soil samples were collected from Okanagan orchards approximately 24 hours after an irrigation, at depths of 4-8 and 10-14 inches. A total of 93 samples was obtained, of known volume. The field capacity of each was determined, expressed both in per cent by weight and in inches of water per foot of soil. Greenhouse determinations were made of the wilting coefficient. The "available" moisture was determined by deducting the wilting coefficient from the field capacity. Laboratory determinations were made of the moisture equivalent, the settling volume, the mechanical analysis, and the organic matter content.

No effect of organic matter content was apparent on the field capacity at each location. In most cases, the 4-8 inch sample had a higher organic matter content, a lower colloid content, and a lower field capacity than the 10-14 inch sample.

High coefficients of correlation were obtained between the laboratory determinations on the one hand and field capacity, wilting coefficient and available moisture on the other hand. Still higher coefficients were obtained among the laboratory determinations.

Second degree polynomial equations were calculated for determining field capacity, wilting coefficient and available moisture from each of the laboratory determinations. The standard errors of estimate were high, ranging mostly between 10 and 20 per cent of the means. The best all-round laboratory measurement for use in indirect determination of the three moisture measurements proved to be the moisture equivalent. However, the percentage sand and percentage colloid also proved reasonably satisfactory.

Evidence is presented to indicate that as the soil particles become finer, the moisture content available for plant use increases to a certain point only. The maximum content of available moisture was obtained at a clay content of around 35 per cent.

[*Appendix (Table 4) on pages 576-578*]

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APPENDIX

TABLE 4.—SUMMARY OF SOILS DATA

Sample No.	Sand	Silt	Clay	Colloid	Organic matter	Volume weight	Settling volume	Moisture equivalent	Field capacity*		Wilting coefficient*	
	%	%	%	%	%		cc.	%	%	in.	%	in.
1a**	63.4	28.0	8.6	14.5	—	1.52	40.0	11.4	16.4	2.99	3.6	0.66
2a	74.4	18.9	6.7	11.3	0.75	1.55	37.0	7.8	11.8	2.21	2.8	0.52
2b	67.0	26.1	6.9	13.9	0.50	1.58	37.0	9.6	16.6	3.15	3.2	0.61
3a	63.1	27.5	9.4	15.0	—	1.47	38.0	7.8	14.4	2.57	3.5	0.62
3b	58.0	32.2	9.8	16.6	0.13	1.39	40.0	11.2	26.0	4.35	—	—
4b	70.4	18.6	11.0	15.1	0.03	1.48	36.0	8.0	19.5	3.34	3.2	0.57
5a	86.5	8.1	5.4	6.6	—	1.51	34.0	3.6	6.7	1.24	1.4	0.25
5b	85.4	7.7	6.9	8.1	0.02	1.55	33.0	3.8	7.2	1.34	1.7	0.32
6a	56.6	30.9	12.5	18.9	0.77	1.44	43.0	12.4	21.9	3.79	4.5	0.78
6b	59.4	31.0	9.6	17.4	0.34	1.48	41.0	12.2	22.8	4.06	3.9	0.69
7a	75.4	15.1	9.5	12.2	0.18	1.54	37.5	7.0	12.6	2.33	2.6	0.48
7b	69.0	23.7	7.3	10.9	—	1.50	37.0	5.6	14.3	2.58	2.7	0.49
8a	60.9	28.1	11.0	17.7	1.13	1.41	44.0	9.6	18.6	3.14	3.7	0.63
9a	45.1	26.1	28.8	37.8	—	1.37	50.0	20.6	27.4	4.50	7.6	1.25
10a	42.5	32.0	25.5	36.5	1.48	1.40	52.5	20.8	24.3	4.11	6.6	1.11
11a	56.6	31.4	12.0	16.5	1.30	1.43	42.0	10.4	22.5	3.85	5.8	1.00
12a	58.6	27.8	13.6	20.1	1.40	1.46	45.0	10.8	20.3	3.57	5.7	1.00
12b	61.5	28.2	10.3	17.8	—	1.49	41.5	10.2	21.1	3.78	6.0	1.07
13a	59.4	26.7	13.9	23.3	0.78	1.49	43.0	11.0	16.2	2.89	4.3	0.77
13b	60.2	29.3	10.5	15.6	0.29	1.40	40.5	9.0	16.4	2.76	3.1	0.52
14a	71.6	21.0	7.4	11.7	0.17	1.67	35.0	6.0	10.9	2.19	3.2	0.64
14b	86.9	8.5	4.6	6.8	—	1.67	30.5	2.8	7.0	1.40	2.0	0.40
15a	78.7	14.0	7.3	10.5	0.80	1.55	36.0	5.8	11.0	2.06	1.9	0.35
15b	75.3	16.9	7.8	11.5	0.24	1.59	34.5	5.0	11.6	2.22	2.4	0.46
16a	58.4	30.4	11.2	17.5	—	1.57	34.0	4.4	10.0	1.89	2.2	0.41
16b	85.9	7.7	6.4	8.2	—	1.48	35.0	3.8	8.4	1.49	2.3	0.41
17b	59.0	30.0	11.0	18.5	—	1.38	43.0	10.0	19.3	3.10	4.5	0.75
18a	58.2	30.1	11.7	19.3	—	1.42	39.5	10.2	18.2	3.12	4.2	0.72
19a	35.0	31.8	33.2	44.6	1.50	1.23	55.5	23.6	34.0	5.06	9.3	1.37
19b	29.2	39.2	31.6	45.2	0.67	1.29	52.5	24.6	32.8	5.10	9.4	1.46
20a	55.9	31.4	12.7	17.8	0.97	1.44	42.0	11.2	22.6	3.99	5.1	0.88

21a	49.0	34.4	16.6	26.0	1.00	1.35	48.0	14.0	20.4	3.31	5.3	0.86
21b	50.6	35.2	14.2	23.5	1.03	1.37	45.5	13.0	20.3	3.33	5.8	0.95
22a	46.6	39.2	14.2	28.1	0.78	1.46	47.0	13.4	18.6	3.25	4.3	0.75
22b	21.9	52.5	25.6	53.2	0.45	1.34	52.0	20.6	26.5	4.26	6.2	1.00
23a	34.5	47.3	18.2	38.1	1.13	1.37	52.0	16.0	20.8	3.42	6.3	1.04
23b	12.6	58.0	29.4	57.5	0.70	1.29	57.0	26.8	28.5	4.43	7.2	1.12
24a	37.6	46.7	17.7	32.6	1.00	1.3	50.0	16.2	22.1	3.55	6.1	0.97
24b	18.6	54.7	26.7	50.1	0.37	1.31	54.0	22.6	28.9	4.55	6.2	0.98
25a	48.2	32.3	19.5	27.7	1.30	1.46	47.0	15.8	22.5	4.03	—	—
25b	45.8	34.6	19.6	28.8	1.21	1.27	49.5	18.8	29.0	4.45	9.2	1.40
26a	72.4	21.0	6.6	11.2	0.67	1.67	33.5	5.4	11.1	2.22	2.3	0.46
26b	70.2	21.0	8.8	12.6	0.50	1.63	34.5	6.2	12.4	2.44	2.8	0.55
27a	10.6	39.8	49.6	60.8	1.98	1.29	58.5	23.2	30.7	4.78	—	—
28a	53.0	36.0	11.0	17.8	1.12	1.45	42.0	11.8	21.9	3.81	4.5	0.78
28b	65.4	20.4	14.2	18.4	0.63	1.47	42.0	12.8	21.0	3.70	—	—
29a	30.0	48.0	22.0	40.0	1.03	1.27	48.5	20.6	29.0	4.41	—	—
29b	31.2	45.2	23.6	41.8	0.72	1.35	50.0	20.4	28.3	4.60	6.6	1.07
30a	24.4	47.4	28.2	48.2	0.52	1.31	54.5	21.4	30.7	4.81	5.8	0.91
30b	4.6	60.2	35.2	59.2	0.29	1.25	55.5	28.2	34.0	5.12	7.8	1.17
31a	54.0	30.8	15.2	24.8	1.22	1.42	43.7	11.8	17.1	2.92	4.8	0.82
31b	47.8	36.6	15.6	26.0	0.85	1.34	45.5	13.0	24.4	3.92	4.6	0.74
32a	52.4	31.2	16.4	23.0	0.99	1.43	44.0	12.8	23.8	4.09	4.8	0.82
33a	55.2	38.2	6.6	9.6	0.20	1.59	34.0	4.6	14.1	2.68	2.2	0.42
33b	84.4	8.6	7.0	7.2	0.23	1.63	33.0	3.2	10.6	2.08	2.0	0.39
34a	88.2	6.4	5.4	6.9	0.27	1.45	34.5	3.4	6.6	1.15	1.6	0.28
34b	88.4	5.4	6.2	8.9	0.03	1.43	33.5	3.0	7.3	1.26	1.6	0.28
35a	84.6	10.0	5.4	8.4	0.24	1.45	34.0	3.6	9.1	1.58	2.0	0.35
35b	87.8	6.4	5.8	6.8	0.02	1.46	33.5	2.8	7.3	1.28	—	—
36a	83.8	6.4	9.8	9.2	0.47	1.46	34.5	4.0	8.3	1.46	1.8	0.32
36b	88.0	5.6	6.4	9.1	0.03	1.46	33.5	3.4	6.0	1.06	1.6	0.28
37a	62.8	14.4	22.8	28.6	2.10	1.42	52.0	16.8	24.5	4.19	7.1	1.21
38a	38.4	39.2	22.4	35.6	2.12	1.37	54.0	16.6	24.3	4.00	8.0	1.32
39a	59.6	25.0	15.4	16.4	1.52	1.54	41.0	11.2	16.5	3.06	4.5	0.83
39b	58.6	25.8	15.6	20.7	0.73	1.50	42.0	9.2	18.8	3.38	4.4	0.79
40a	61.6	23.4	15.0	21.8	1.83	1.41	44.0	11.6	18.3	3.10	5.0	0.85
41a	38.4	36.2	25.4	35.4	0.75	1.41	51.0	19.0	23.9	4.05	6.8	1.15
41b	29.8	34.4	35.8	53.8	0.71	1.41	54.0	21.6	26.0	4.41	8.0	1.36
42a	44.0	36.5	19.5	31.0	1.70	1.33	50.5	17.0	22.0	3.52	—	—
42b	40.0	42.6	17.4	29.8	0.74	1.38	48.5	15.4	24.0	3.97	5.4	0.89

* Each of these two moisture contents is expressed in two ways: first, in percentage dry weight of soil; and second, in inches of water per foot of soil.
** At each location, samples were taken at depths of (a) 4 to 8 inches and (b) 10 to 14 inches. Samples containing gravel were discarded.

APPENDIX—*Continued*

TABLE 4.—SUMMARY OF SOILS DATA—*Continued*

Sample No.	Sand	Silt	Clay	Colloid	Organic matter	Volume weight	Settling volume	Moisture equivalent	Field capacity*		Wilting coefficient*	
	%	%	%	%	%		cc.	%	%	in.	%	in.
43a**	65.6	24.4	10.0	11.6	0.75	1.43	40.0	8.8	14.6	2.52	3.4	0.58
43b	59.4	31.0	9.6	18.0	0.67	1.51	41.0	8.2	16.5	2.99	3.5	0.63
44a	24.6	34.0	41.4	58.4	0.85	1.21	54.0	21.8	31.0	4.49	9.5	1.38
44b	6.2	33.8	60.0	79.8	0.32	1.23	61.5	30.8	32.9	4.84	9.3	1.37
45a	27.2	41.4	31.4	42.6	0.62	1.37	51.5	17.8	26.5	4.35	7.3	1.20
45b	20.4	38.4	41.2	52.9	0.44	1.41	53.5	22.2	21.1	3.55	8.5	1.44
46a	26.0	27.4	46.6	58.2	1.32	1.28	60.0	24.0	28.6	4.42	—	—
46b	6.4	34.4	59.2	78.4	0.25	1.17	61.0	34.4	35.9	5.06	11.7	1.64
47a	31.6	35.2	33.2	52.2	0.83	1.20	56.0	23.4	30.1	4.36	9.1	1.31
47b	23.2	34.2	42.6	61.8	0.40	1.23	56.0	25.6	30.7	4.53	7.9	1.17
48a	36.8	38.0	25.2	36.6	1.60	1.27	54.0	18.0	27.3	4.16	8.5	1.30
48b	37.6	36.6	25.8	33.0	0.97	1.38	49.0	17.0	25.8	4.27	7.2	1.19
49a	60.6	32.2	7.2	17.0	1.10	1.46	43.0	9.2	18.2	3.18	3.6	0.63
49b	56.0	34.0	10.0	15.2	1.25	1.40	43.5	11.6	16.9	2.84	3.6	0.60
50a	58.8	32.2	9.0	16.5	1.03	1.44	43.0	9.4	16.1	2.78	4.7	0.81
50b	60.0	33.0	7.0	15.0	0.59	1.45	41.0	11.8	20.6	3.59	4.6	0.80
51a	65.6	25.1	9.3	15.2	0.95	1.48	38.0	7.4	12.3	2.18	2.6	0.46
51b	67.0	27.0	6.0	10.6	0.62	1.49	37.5	7.0	14.2	2.53	3.8	0.68
52a	65.6	25.0	9.4	15.4	—	1.41	39.5	9.0	15.8	2.69	3.3	0.56
53a	13.4	29.8	56.8	76.6	0.34	1.24	62.0	30.4	33.8	5.04	12.4	1.84
53b	10.0	18.8	71.2	83.8	0.02	1.22	64.0	35.0	34.7	5.11	13.3	1.95
54a	39.8	41.2	19.0	31.4	1.07	1.42	49.0	15.4	22.2	3.78	5.4	0.92
54b	12.6	53.6	33.8	60.0	0.77	1.30	57.0	25.6	30.9	4.84	—	—

* Each of these two moisture contents is expressed in two ways: first, in percentage dry weight of soil; and second, in inches of water per foot of soil.
** At each location, samples were taken at depths of (a) 4 to 8 inches and (b) 10 to 14 inches. Samples containing gravel were discarded.

FEEDING GRAINS OF DIFFERENT PROTEIN CONTENT TO GROWING PIGS[1]

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In experiments reported recently from this Department (3) it was observed that when grain constituted the only source of protein in rations for rats and pigs, the protein content of the grains used had a marked influence on the rates of gain of both species. The results obtained from groups of pigs fed a mixed protein supplement at an arbitrary level without regard to the protein content of the grain in the basal ration, showed that the grain replacement value of a pound of protein supplement was almost 2.8 times greater when used with grains averaging 9.2 per cent in protein content than when added to grains containing 16.6 per cent protein. Data obtained from a pig feeding trial designed to study the effect of adjusting the level of protein supplementation with reference to the protein content of the grains in the basal ration are reported in the present paper.

EXPERIMENTAL

Selection and Analysis of Grains

Nitrogen determinations were done on a large number of samples of grain grown in different soil zones of Alberta in 1947. On the basis of these analyses, samples of oats and barley representing a wide range in protein content were selected and bulk quantities were purchased for the feeding trial. With a view to eliminating differences in feeding value which might be attributable to variety an attempt was made to select high, medium and low protein samples of one variety of each grain, but in the case of barley this was not possible, and, as is shown in Table 1, the high protein barley sample finally selected was of the Trebi variety, while the low and medium protein samples were Olli. The bulk quantities were resampled for analysis after delivery. Data for the protein content ($N \times 6.25$) of these grains obtained from two or more analyses in duplicate on 1 gram samples by the Kjeldahl-Gunning-Arnold method (1) using mercuric oxide as catalyst, and for crude fibre content as determined by the A.O.A.C. method (1), are summarized in Table 1.

[1] This study was conducted with the aid of a grant from the Committee on Agricultural Research Grants, University of Alberta.

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Table 1.—Variety and analyses of grains

(Basis 13.5 per cent moisture)

Grain	Variety	Protein	Fibre
		%	%
Low protein oats	Eagle	9.5	10.8
Medium protein oats	Eagle	11.5	10.5
High protein oats	Eagle	15.9	11.6
Low protein barley	Olli	9.1	6.1
Medium protein barley	Olli	12.2	6.6
High protein barley	Trebi	15.2	6.0

TABLE 2.—RATIONS

(During period A all groups were supplemented with feeding oil at a rate of 8 ml. per pig per day. The feeding oil contained 1200 I.U. vitamin A and 200 I.U. vitamin D per gram)

Feed	Grain + minerals + vitamins						Grain + minerals + vitamins + protein					
	1 L.P.		2 M.P.		3 H.P.		4 L.P.		5 M.P.		6 H.P.	
	A*	B*	A	B	A	B	A	B	A	B	A	B
Low protein oats, lb.	39	9	—	—	—	—	33	9	—	—	—	—
Low protein barley, lb.	59	89	—	—	—	—	51	81	—	—	—	—
Medium protein oats, lb.	—	—	39	9	—	—	—	—	36	9	—	—
Medium protein barley, lb.	—	—	59	89	—	—	—	—	54	86	—	—
High protein oats, lb.	—	—	—	—	39	9	—	—	—	—	37.75	9
High protein barley, lb.	—	—	—	—	59	89	—	—	—	—	56	87.50
Iodized salt, lb.	1	1	1	1	1	1	—	—	—	—	0.25	0.25
Ground limestone, lb.	1	1	1	1	1	1	—	—	—	—	—	0.25
Mixed supplement, lb.	—	—	—	—	—	—	16	10	10	5	6	3
Protein in ration, per cent**	9.1	9.0	11.7	11.9	15.2	15.0	13.8	12.0	14.5	13.4	16.8	15.9
Fibre in ration, per cent**	7.8	6.4	8.0	6.8	8.1	6.4	7.6	6.5	7.9	6.9	8.1	6.5

* Period A—start of experiment to 110 lb.; Period B—110 lb. to market weight, all groups.
** Basis 13.5 per cent moisture.

Feeding Trial

Purebred Yorkshire weanling pigs from the University of Alberta swine herd were used in this trial. Six lots of seven pigs each were made up to be comparable with respect to litter, sex and initial weight. They were housed in pens 10 ft. × 12 ft. without access to soil or sunlight.

The feeding trial was divided into two periods: period A—30 to 110 lb.; period B—110 lb. to market weight. During period B the proportion of barley to oats in the ration was increased and the amount of protein supplement was decreased. The pigs were hand-fed three times daily until they reached an average weight of 110 lb. and twice daily thereafter.

The rations for lots 1, 2 and 3 were composed of low, medium and high protein grains, respectively, supplemented with iodized salt, ground limestone and feeding oil. For these lots the grains comprised the only source of protein in the ration. In addition to the grains, lots 4, 5 and 6 were given feeding oil and graded amounts of mixed protein-mineral supplement, depending upon whether the grains used were low, medium or high in protein. The following rates of supplementation were employed during periods A and B, respectively: lot 4, low protein grains, 16 per cent and 10 per cent; lot 5, medium protein grains, 10 per cent and 5 per cent; lot 6, high protein grains, 6 per cent and 3 per cent. In view of the small proportion of mixed supplement in the ration of lot 6, this group was given additional iodized salt and ground limestone. The feeding oil was omitted from the rations for all groups after the pigs reached an average weight of 110 pounds.

The mixed supplement used in the rations for lots 4, 5 and 6 contained 37.4 per cent protein and 5.6 per cent fibre on a 13.5 per cent moisture basis, and was composed of the following: tankage 50, linseed oil meal 25, fish meal 7, alfalfa meal 8, ground limestone 5 and iodized salt 5 pounds per hundred.

The rations fed are listed in detail in Table 2.

RESULTS AND DISCUSSION

A summary of the results of the feeding trial is presented in Table 3.

Reference to the results shown in Table 3 for lots 1, 2 and 3 shows that the protein content of the grains used had a marked effect on the rate of gain and feed consumption per unit gain when the grains comprised the only source of protein in the ration. These data are in good agreement with those of McElroy, Lobay and Sinclair (3). The rate of gain for lot 1, fed low protein grains, was 0.35 lb. per day slower than that for lot 3, fed high protein grains, and the feed consumption per 100 lb. gain was 24 per cent greater. Lot 2, fed medium protein grains, was intermediate between lots 1 and 3 in rate and economy of gain.

That a substantial reduction in the amount of supplementary protein required in swine rations may be possible, dependent upon the protein content of the cereal portion of the ration, is shown by the results obtained for lots 4, 5 and 6. Though there were no marked differences between the results for these lots it is significant that the pigs of lot 6, fed a ration in which only 10 per cent of the total protein was contributed by the mixed supplement, made slightly faster gains and more efficient use of feed than

TABLE 3.—LOW, MEDIUM AND HIGH PROTEIN GRAINS FOR PIGS

Lot number	1	2	3	4	5	6
Description of ration	Grain + minerals + vitamins			Grain + minerals + vitamins + protein		
	L.P.	M.P.	H.P.	L.P.	M.P.	H.P.
Mean protein in ration, per cent	9.1	11.8	15.1	13.0	14.0	16.4
Protein from:						
Grain, per cent	100	100	100	62	80	90
Mixed supplement, per cent	—	—	—	38	20	10
Number of pigs in lot	7	7	7	7	7	7
Average initial weight, lb.	28.3	28.4	29.0	29.3	29.1	29.8
Average final weight, lb.	196.3	200.6	203.9	207.8	204.0	204.8
Average number days on experiment	208	183	151	137	141	132
Total gain, lb.	1176	1205	1224	1250	1224	1225
Average daily gain, lb.	0.81	0.94	1.16	1.30	1.24	1.32
Average daily feed, lb.	3.72	3.82	4.31	4.81	4.78	4.64
Feed required for 100 lb. gain:						
Grain, lb.	451.8	398.1	364.7	324.1	358.5	334.2
Mixed supplement, lb.	—	—	—	45.2	27.0	14.5
Ground limestone, lb.	4.6	4.1	3.7	—	—	0.5
Iodized salt, lb.	4.6	4.1	3.7	—	—	0.8
Total, lb.	461.0	406.3	372.1	369.3	385.5	350.0
Average Advanced Registry Carcass Score, per cent	37.3	57.6	65.0	71.0	65.7	70.7

did the pigs of lots 4 and 5, fed rations in which 38 per cent and 20 per cent, respectively of the total protein was derived from the supplement. The results for lots 4 and 6 show that 30.7 lb. of mixed supplement were saved at a cost of 10.1 lb. of grain, a saving attributable to the high protein content of the grains fed to group 6.

The data for lot 3, fed a ration containing 15.1 per cent protein of grain origin, confirm the knowledge that the quality of cereal proteins is inadequate to support optimum growth in swine. It appears, however, that if the grains contain a sufficient quantity of protein to provide a substantial amount of plant protein in the ration, good results can be obtained by supplementation with relatively small amounts of high quality protein.

Annual reports of the Board of Grain Commissioners for Canada (2), in which the protein content of carlot samples of barley selected from different crop districts in Western Canada is reported, indicate that in certain areas a considerable volume of the barley produced contains either less than 10 per cent or more than 14 per cent protein. The results of the experiment described in this paper suggest that when grains of high protein content are available the usual recommendations regarding rates of protein supplementation may be revised downward. Conversely, although additional experiments are required to show whether it is likely to be economical to fortify grains of low protein content with unusually high levels of supple-

ment, the results of this and a previously reported study (3) emphasize the special value of protein supplement in swine rations based on low protein grains.

Representatives of the Production Service of the Dominion Department of Agriculture co-operated in cutting and scoring the carcasses from this experiment by the Advanced Registry method. It is shown in the last line of Table 3 that the average carcass score for group 1 fed low protein grains, supplemented simply with ground limestone, salt and feeding oil, was only 37.3 per cent. These pigs were on test for 7 months and were about 9 months old when marketed at 200 pounds. The detailed score showed that their carcasses were, if anything, a little shorter than those of the other groups; they were also fatter as indicated by depth of fat at shoulder, back and loin and by a high dressing percentage. The muscles of these pigs, fed a ration deficient in both amount and quality of protein, were small and poorly developed, as shown by the area of the eye of lean and by the low belly score which averaged only 44.3 per cent of the maximum obtainable under the Advanced Registry system of scoring. These results for lot 1, as well as those for lot 2, simply emphasize the well-known fact that pigs that are fed unbalanced rations and grow slowly all the way from weaning to market weight are likely to yield poor carcasses.

SUMMARY

An experiment is described in which the feeding value for swine of grains of high, medium and low protein content was studied. The results confirm those reported in a previous paper in which it was shown that when grains constitute the only source of protein in the ration, the rate and economy of gain in pigs is markedly influenced by the protein content of the grains employed. It is also shown that when high protein grains are used in the ration, good results can be obtained by adding substantially smaller quantities of protein supplement than are required when the grains used are of low protein content.

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ERADICATION OF POISON IVY (*RHUS RADICANS* L.)

IV. EXPERIMENTS WITH AMMONIUM SULFAMATE AND SODIUM CHLORATE[1]

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Investigations were initiated at Ottawa, Ontario, in 1941 to test the herbicidal properties of ammonium sulfamate on poison ivy. Their purpose was three-fold: (A) to compare the effectiveness of ammonium sulfamate and sodium chlorate, (B) to investigate the relationship between dosage and control, and (C) to determine the best time of year for application. The results reported here are from plots treated in 1942 and 1943, together with follow-up treatments made on some of these plots in 1944 and 1945.

REVIEW OF LITERATURE

Preliminary tests to evaluate sulfamates as weed killers were reported by Cupery and Cupery (6) in 1939. Poison ivy was one of the plants under test and these investigators observed that it was particularly sensitive to ammonium sulfamate applied as a spray. Dietz, Vogel, and Cupery (7) recorded further observations on these 1939 test plots and gave results obtained from treatments made in 1940. They could find no noticeable difference in ultimate efficiency between ammonium sulfamate and sulfamic acid. The rapidity of action of ammonium sulfamate was found to be influenced by humidity and rainfall, and to some extent by temperature. They concluded that ammonium sulfamate properly applied was an effective weed killer for poison ivy. Yeager and Calahan (16) gave the results of two years' tests on poison ivy in which sodium chlorate was compared with ammonium sulfamate. Sodium chlorate applications gave a very poor control whereas those with ammonium sulfamate gave an almost complete kill. Southwick (12) studied the effect of ammonium sulfamate applications on poison ivy growing under apple trees. Concentrations of $\frac{1}{2}$, $\frac{3}{4}$, and 1 pound per gallon of water killed the ivy foliage but some recovery occurred the following year. Flory (8), Grigsby (9), and Jacques and Meilleur (10) secured a complete kill of poison ivy with applications of ammonium sulfamate. Their reports refer, however, only to the year in which the materials were applied and do not include observations made in the year following the treatment. Cross (5) mentioned very briefly the effect of ammonium sulfamate sprays on poison ivy in cranberry bogs.

Although it was first investigated as a herbicide in 1939, ammonium sulfamate was reported to have received widespread tests as an eradicant for poison ivy in 1941, 1942, and 1943 (1, 2). Reports of community-sponsored campaigns to eradicate poison ivy with ammonium sulfamate have been published by Tapley (13) and Towle (14).

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MATERIALS AND METHODS

In the present experiments, the plots, each 100 square feet in area, were on open ground in the vicinity of Ottawa West, Ontario. The soil was a very shallow Farmington loam over limestone bedrock. Stones were numerous on the surface of many of the plots. Poison ivy was quite thick, with an average ground cover of 80 per cent and upright stems ranging from 18 to 24 inches in height. Although the areas suitable for the experiments were rather small, they were in close proximity and were similar in respect to poison ivy cover. All applications were made to the ivy foliage with a Brown's No. 4 "Open-hed" sprayer. Treatments were made in two successive years rather than being replicated in any one year.

Estimates of the percentage cover of poison ivy were made visually before and after each application. They represent ground cover, that is to say, the percentage of the area of the plot covered with poison ivy, but they do not take into account the density of the foliage in the completely covered areas.

The ammonium sulfamate was relatively pure and was secured from the Grasselli Chemicals Department of E. I. du Pont de Nemours & Co., through the courtesy of B. L. Emslie of Canadian Industries Ltd., Montreal. The sodium chlorate was purchased from the Electric Reduction Sales Co., Ltd., of Toronto.

EXPERIMENTS AND RESULTS

Rate of Application

Other conditions being equal, dosage—the quantity of toxicant applied per unit of area—may be changed by varying gallonage or concentration. In this experiment, gallonage—the amount of herbicidal solution—was kept constant and the concentration of the solution was varied. The gallonage used was one Imperial gallon per 100 square feet. This gallonage permitted thorough spraying of the plots in two directions. A certain amount of run-off occurred. The concentrations investigated were 10, 6.7, 5, and 4 per cent. The 1942 treatments were applied between 1.30 and 3.00 p.m. on June 9, and those of 1943, between 2.00 and 4.00 p.m. on June 18. Since up to the time that the 1943 applications were made, no poison ivy had yet recovered on any of the plots sprayed with ammonium sulfamate in the previous year, a fifth and weaker concentration (3.3 per cent) was also applied. In addition, to obtain preliminary information on the effect of decreasing the gallonage of ammonium sulfamate, applications of ½ gallon of 5 and of 10 per cent solution were included in the 1943 experiment. These treatments were made on an adjacent area of poison ivy on June 16, 1943, between 3.00 and 3.45 p.m. The amounts of materials used in the various treatments are given in Table 1.

The season in 1942 was earlier than in 1943, so that the plants were in approximately the same stage of growth, and therefore phenologically comparable on the respective dates of application. Clear and sunny weather prevailed on the days the herbicides were applied. In 1942 the weather was dry whereas in 1943 it was much wetter than average (Table 6). Rainfall, with the amount in inches given in brackets, was recorded for the

Table 1.—Quantity of material and equivalent coverages for the different herbicidal applications

Dosage		Weight of herbicide	Equivalent coverage for 1 pound of herbicide	Equivalent number of pounds per acre
gal.	conc. %	oz.	sq. ft.	lb.
1	10	16	100	436
1	6.7	10.6	150	290
1	5	8	200	218
1	4	6.4	250	174
1	3.3	5.3	300	145
0.5	10	8	200	218
0.5	5	4	400	109

period immediately before and after the applications, as follows: 1942—June 6 (0.15) and June 13 (0.42); 1943—June 15 (1.73), 17 (0.58), 19 (0.05), 26 (0.33), and June 27 (1.30).

Table 2 gives the results obtained from the applications of the five different concentrations. Figure 1 gives the dosage-response curves obtained when percentage reduction of poison ivy is plotted against the logarithm of these concentrations.

With ammonium sulfamate, the control of poison ivy varied from good to excellent for the 1942 applications and from fair to good for those made in 1943. With sodium chlorate, the control varied from fair to good

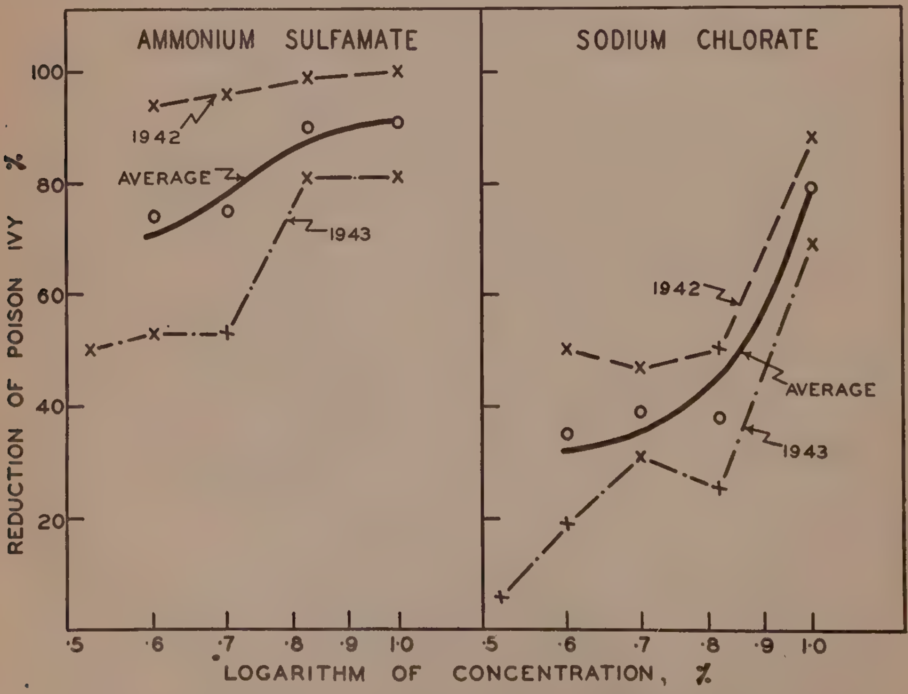

Figure 1. Dosage-mortality curves, showing the effect of ammonium sulfamate and sodium chlorate on poison ivy (the dosages were 1 gallon per 100 sq. ft. of 3.3, 4, 5, 6.7, and 10 per cent solutions).

for the 1942 applications and from poor to fair for those made in 1943. Although in 1942 the level of control obtained with all concentrations of both herbicides was higher than for the corresponding concentration in 1943, the slope of the curves for both years was somewhat similar for increase of concentration in the sprays. While, therefore, some factor caused a different level of control in the two years, the effect of increasing the concentration, i.e., the relationship of dosage to control, was approximately the same in both years.

A significant difference in the control of poison ivy from increase of concentration was evident between ammonium sulfamate and sodium chlorate. With ammonium sulfamate, the control from concentrations of 4 and 5 per cent was only slightly inferior to that obtained from concentrations of 6.7 and 10 per cent. With sodium chlorate, however, the control from concentrations of 4, 5, or 6.7 per cent was definitely inferior to that obtained from the 10 per cent solution. While the slope of the curve, therefore, rises rapidly from the 6.7 to the 10 per cent concentration for sodium chlorate it levels off at these concentrations for ammonium sulfamate (Fig. 1).

TABLE 2.—EFFECTS OF AMMONIUM SULFAMATE AND SODIUM CHLORATE APPLIED AS FOLIAGE SPRAYS TO POISON IVY ON JUNE 9, 1942, AND ON JUNE 16 AND 18, 1943

Dosage		Percentage reduction in July of the second year after application					
		Ammonium sulfamate			Sodium chlorate		
		1942 application	1943 application	Average	1942 application	1943 application	Average
gal.	conc. %	%	%	%	%	%	%
1	10	100	81	91	88	69	79
1	6.7	99	81	90	0	25	38
1	5	96	53	75	47	31	39
1	4	94	53	74	50	19	35
1	3.3	—	50	—	—	6	—

Time of Application

To determine the best time of year to apply herbicides for the control of poison ivy, a single application of ammonium sulfamate and of sodium chlorate was applied as a spray in each of the four months—June, July, August, and September—of 1942 and 1943. The dosage selected was 1 gallon of a 10 per cent solution for each plot. In 1942, a grass fire overran the experimental area during the first week of August making it impossible to carry out the August and September treatments. Previously, however, treatments had been made on June 8 and July 15. The 1943 treatments were made on June 16, July 13, August 6, and September 8. All treatments were made in the early afternoon (2.00-3.00 p.m.) except those of July, 1942, which were made at 7.00 p.m.

All days on which treatments were applied were clear and sunny. Rainfall was recorded on the day following the June, August, and September treatments in 1943, but following the treatments in June and July, 1942, and in July, 1943, a 2- to 6-day interval elapsed before any rain fell. In

1943, owing to the high rainfall, the poison ivy in the plots remained in an active state of growth much later than usual. As a result, the foliage was dark green in colour throughout most of August and only one-quarter of the leaves were assuming their autumnal coloration by September 8. This condition was in marked contrast to that in 1942, when, owing to dry weather, some of the ivy leaves were turning a red or yellow colour at the time of the July treatment.

To obtain information on the efficiency of these herbicides when used in follow-up treatments, it was proposed to continue the applications each year, and in the same month as the original treatment, until the poison ivy was eradicated. Unfortunately a new housing sub-division was opened up in 1946 in the vicinity of the plots and it was necessary to abandon the experiment before final treatments could be made.

Table 3 gives the differences in control obtained from the applications of ammonium sulfamate and sodium chlorate made in June, July, August, and September. With ammonium sulfamate, there was no significant difference between the control obtained from applications made in June or July. Applications made in both these months gave excellent control and resulted in a greater reduction of poison ivy than was obtained from applications made in August or September. With sodium chlorate, the control was good, fair to poor, poor, and zero for applications made in June, July, August, and September, respectively. Not only did applications of ammonium sulfamate give better control of poison ivy than did those of sodium chlorate but the results indicated that the period of time during the growing season in which good control can be expected is longer for ammonium sulfamate than for sodium chlorate treatments.

Table 3.—Effectiveness of ammonium sulfamate and sodium chlorate on poison ivy when applied as foliage sprays in each of June, July, August, and September

Herbicide	Month	Percentage reduction in July of first year aft r application	
		1942 application	1943 application
		%	%
Ammonium sulfamate (1 lb. in 1 gal. water per 100 sq. ft.)	June	99	94
	July	93	98
	Aug.	—*	53
	Sept.	—*	78
Sodium chlorate (1 lb. in 1 gal. water per 100 sq. ft.)	June	95	78
	July	29	67
	Aug.	—*	29
	Sept.	—*	0

* Grass fire removed foliage from the plots before treatment could be made.

In the follow-up treatments consisting of one herbicidal application per year for 3 successive years, the June and July applications again gave the best results with both ammonium sulfamate and sodium chlorate (Table 4). Complete eradication was obtained from 2 and 3 years of treatments, respectively, for applications of ammonium sulfamate made in June and July. To reduce a dense stand of poison ivy to a few scattered

TABLE 4.—THE EFFECT OF REPEATING HERBICIDAL APPLICATIONS ONCE EACH YEAR FOR THREE YEARS (AVERAGE RESULTS FOR TWO TREATMENTS)

Herbicide	Month of treatment	Average ground cover of poison ivy			
		Year of treatment			Year following completion of treatment
		1	2	3	1
		%	%	%	%
Ammonium sulfamate (1 lb. in 1 gal. water per 100 sq. ft.)	June	85	3*	0	0
	July	85	4	1	0
	Aug.	85	50	1	1
	Sept.	85	35	10	2
Sodium chlorate (1 lb. in 1 gal. water per 100 sq. ft.)	June	85	12	2	1
	July	80	45	5	1
	Aug.	85	60	55	8
	Sept.	70	70	65	50

* Due to the small size of the plants in the second year it was necessary to defer treatment until July.

plants required 1, 1, 2, and 3 years, respectively, for applications of this chemical made in June, July, August, and September. The total amounts of herbicide required to bring about this reduction were 1.0, 1.0, 2.0, and 2.5 pounds, respectively. With sodium chlorate, complete eradication was not obtained from any of the treatments for the three successive years. The applications made in June and July reduced a dense stand of ivy to a few scattered plants, the 2 and 3 years of treatment requiring 1.7 and 2.5 pounds of chlorate, respectively. The August treatments reduced the poison ivy a considerable amount but, even after a total of 3 pounds of chlorate had been applied in the 3 applications, a fair number of clumps were still present. The chlorate sprays in September did not reduce the stand of poison ivy an amount sufficient to be considered satisfactory control. Although it was not possible to carry this part of the experiment through to its conclusion, it is quite evident that fewer treatments were required with ammonium sulfamate than with sodium chlorate to eradicate completely poison ivy and best results with both herbicides were obtained from applications made in June or early July.

A Comparison of the Effect of Ammonium Sulfamate with that of Sodium Chlorate

From the results obtained under rate of application and time of application, it is quite evident that, under comparable conditions and on a basis of equal weight, better control was obtained with ammonium sulfamate than with sodium chlorate. It was also noted during the experiments that ammonium sulfamate killed a greater proportion of the grass than did sodium chlorate.

The action of ammonium sulfamate and sodium chlorate on the poison ivy foliage was quite similar. Following the application of the solution to the foliage, the leaves gradually turned brown and became curled, dry, and crisp. After treatments with concentrations of 5 or 10 per cent, the leaves died within 5 to 7 days.

TABLE 5.—THE RECOVERY OF POISON IVY FOLLOWING TREATMENT WITH AMMONIUM SULFAMATE AND SODIUM CHLORATE

Herbicide	Dosage		Date of treatment	Ground cover of new growth poison ivy				
				During year of application			First year after application	Second year after application
				July 15	Aug. 16	Oct. 1	July	July
	gal.	conc. %		%	%	%	%	%
Ammonium sulfamate	1	10	June 9/42	0	0	0	0	0
	1	10	June 18/43	0	0	0	5	15
	1	5	June 9/42	0	0	0	2	3
	1	5	June 18/43	0	0	0	9	35
Sodium chlorate	1	10	June 9/42	1	4	4	8	10
	1	10	June 18/43	1	4	5	20	25
	1	5	June 9/42	2	15	30	35	40
	1	5	June 18/43	3	5	15	45	55

The rate of recovery of the poison ivy following the treatments differed markedly for the two herbicides, as will be seen from Table 5. On the plots sprayed with sodium chlorate, new green leaves were appearing within one month after the treatment, whereas, on those sprayed with ammonium sulfamate, new green leaves did not appear until the summer following the treatment. In none of the treatments made to date with ammonium sulfamate has the author yet observed new growth of poison ivy during the year of treatment, except when weak concentrations, such as 3.3 or 4.0 per cent, were applied—and then only in certain years. The new leaves that developed in the sodium-chlorate treated plots arose from buds on the existing upright stems. They grew quite rapidly. In the ammonium-sulfamate treated plots, however, the new leaves that appeared in the summer following the application were on new stems, sucker growth, and arose direct from the underground root-stalks. These stems were, of course, quite small and some of them did not appear until late in July.

The Possible Effect of Rainfall on the Control of Poison Ivy

In these experiments, treatments made in June, 1942, both with ammonium sulfamate and with sodium chlorate gave better control of poison ivy than did those made in June, 1943. From rainfall data collected at Ottawa by the Field Husbandry Division of the Central Experimental Farm (Table 6), it will be seen that, in 1942, June and July were drier than average, while May and August had approximately an average amount of rainfall. In 1943 although July was quite dry, May, June, and August were much wetter than average. Therefore, the rainfall, and consequently the soil moisture, differed markedly in these two years and might have accounted for the difference in control. Also in 1943, when the July application of ammonium sulfamate gave a slightly better control of poison ivy than that made in June (Table 3)—the opposite of the results usually obtained—July was much drier than was June. Heavy

TABLE 6.—RAINFALL AT OTTAWA, ONTARIO

Month	Fifty-three year average	1942	1943
	inches	inches	inches
April	2.3	1.5	2.4
May	2.7	2.8	4.6
June	3.4	2.0	5.7
July	3.7	2.3	2.2
August	3.0	2.9	9.1
September	2.9	6.5	1.7
October	2.7	2.4	4.3

showers of rain fell during the day previous to and the day following the June application but in July no rain fell for 8 days before or 7 days after the treatment.

Considerable difference was noted in these two years in respect to the effect of ammonium sulfamate on the thin cover of grass present on the plots. All of the 1942 treatments, and to a lesser extent the July treatment in 1943, destroyed most of the grass that was present. In comparison, the June and August treatments in 1943, made during periods of heavy rainfall, had no harmful effect.

Robbins *et al.* (11) state that sodium chlorate can affect plants in different ways: it may act as a contact poison on plant leaves; following its absorption by the leaves, it may serve as a translocated herbicide under certain conditions; and it may kill plants by root absorption. Under conditions of the present experiments, with 1 gallon of solution per 100 square feet, there was run-off on to the soil so that there was opportunity for action both as a translocated spray and as a soil sterilant.

These authors (11) investigated the effect of soil moisture on the translocation of sodium chlorate and obtained a better kill of wild morning-glory *(Convolulus arvensis)* when the soil was dry than when wet. Apparently a high water deficit in the plant brought about better translocation and more complete distribution of toxicant within the roots. Crafts (4) studied the distribution of chlorate in the soil as affected by leaching. His results indicate that chlorate is readily leached downward by water in the soil and that its distribution is largely determined by the amount of water that passes into and through the soil after the chemical is applied. As the soil in the area of the present experiments was prevailingly shallow, the high rainfall in 1943 may have leached the herbicide away from the underground parts of the plants before it could exert its maximum killing power. Therefore, whether the killing of poison ivy by sodium chlorate is due to translocation of the material or to its acting as a soil sterilant, or to a combination of both, it is quite possible that the high rainfall in 1943 accounted for the lower percentage reduction of poison ivy.

That factors other than soil moisture may affect the control of poison ivy when ammonium sulfamate is applied as a herbicide is evident from Table 7. The results given in Table 7 were obtained when different gallonages and concentrations were applied to different locations on June

16 and 18, 1943. A better control of poison ivy was obtained on plots 11 and 12 than on plots 2 and 6 although the former plots received one-half the quantity of solution, and therefore one-half the actual weight of sulfamate. A greater reduction of poison ivy occurred in plot 12 than in plots 2, 6, 8, or 10 although each of these plot received a greater amount of herbicide than did plot 12.

TABLE 7.—THE CONTROL OF POISON IVY WHEN DIFFERENT DOSAGES OF AMMONIUM SULFAMATE WERE APPLIED TO DIFFERENT LOCATIONS AT DIFFERENT DATES

Plot	Date of application	Dose			Reduction of poison ivy
		Gallonage	Concentration	Weight	
	1943	gal.	%	oz.	%
11	June 16	0.5	10	8	98
2	June 18	1.0	10	16	81
12	June 16	0.5	5	4	88
6	June 18	1.0	5	8	53
10	June 16	1.0	3.3	5.3	50
8	June 18	1.0	4	6.4	53

It is not definitely known what factor or factors were responsible for these differences in control but at least two possible causes are worth mentioning. The size of the upright stems of poison ivy differed in the two areas and there was a difference in the amount of rainfall immediately following the applications. Although the areas were in close proximity and the difference in the percentage ground cover of poison ivy was small, there was a denser stand, with higher and coarser stems, on the area containing plots 10, 11, and 12 than on the area containing plots 2, 6, and 8. The area containing plots 10, 11, and 12 was sprayed June 16. On the previous day, 1.73 inches of rain fell and, on the day after the treatment 0.58 inches. The area containing plots 2, 6, and 8, was sprayed on June 18. On the previous day, 0.58 inches of rain fell, but, after the treatment, except for 0.05 inches on the second night, no rain fell until the eighth day. The best control, therefore, was obtained in the plots with the coarsest stems and on which rain fell during the day following the treatments.

While there may be some relationship between the amount of rainfall and the control of poison ivy with ammonium sulfamate or sodium chlorate, experimental work under controlled conditions is required before the importance of rainfall or other environmental factors can be assessed.

DISCUSSION

Insufficient observations were made in these experiments to warrant the drawing of regression lines by plotting the results on logarithmic probability paper, as suggested by Wilcoxon and McCallan (15), or to plot transformed dosage-mortality curves according to Bliss (3). When plotted on semi-logarithmic paper, however, the dosage-response curves for ammonium sulfamate and sodium chlorate (Figure 1) show indications of the sigmoid character found in toxicity studies by many biologists.

The dosage-response curves make possible an evaluation of the recommendation for the eradication of poison ivy of 1 pound of ammonium sulfamate or sodium chlorate per 100 square feet. The levelling-off of the curve with ammonium sulfamate at concentrations of 6.7 and 10 per cent indicates that an increase of the concentration of this material, in the pure salt form, above 7 per cent would give little or no benefit as regards the control of poison ivy. With ammonium sulfamate, therefore, 1 pound per 100 square feet gives a considerable margin of safety and the amount of chemical could be lowered somewhat by either decreasing the concentration or the gallonage. Since, with sodium chlorate, the slope of the curve rises rapidly from the 6.7 to the 10 per cent concentration, definite advantages would be obtained from using a 10 per cent solution. Unfortunately, higher concentrations of sodium chlorate were not included in these experiments, so that it is not known whether the slope of the curve would continue to rise for concentrations just above 10 per cent or whether it would level off. With sodium chlorate, therefore, 1 pound per 100 square feet should be considered a minimum dosage.

From the results obtained, it is evident that, on a basis of equal weight, ammonium sulfamate gives a far better kill of the upright stems of poison ivy than does sodium chlorate. Because of this difference in degree of killing of the upright stems, it was difficult to make comparable estimates of poison ivy recovery. After the application of sodium chlorate, some of the upright stems of poison ivy recovered and put forth new leaves within 3 to 4 weeks. Accurate estimates of recovery, therefore, were possible in the first summer following the treatment. With ammonium sulfamate, however, because of the complete kill of upright stems, new growth did not appear until the next year, and then it came as sucker growth from the underground root stalks. As this new growth was quite small (some of it did not come through the ground until late in July), accurate estimates of recovery were not possible until the second summer after treatment. With ammonium sulfamate treatments, it was necessary to watch the area for at least two years after the application was made in order to make certain that regrowth of poison ivy did not occur.

Differences in time of recovery following the application also affected the timing of follow-up treatments. With sodium chlorate, it was possible to make a second application in the fall of the first year of treatment. With ammonium sulfamate, however, it was necessary to delay the follow-up treatment until the second or third year. In the sulfamate plots where the initial control was only fair, it was possible to make a follow-up treatment in the summer of the first year after the initial application. In those areas, however, where the initial control was excellent, the follow-up treatment could be delayed with advantage until the second summer after the initial application.

SUMMARY

Ammonium sulfamate and sodium chlorate were investigated as eradicants for poison ivy.

With ammonium sulfamate, the average reduction of poison ivy from June applications was 74, 75, 90, and 91 per cent for solution concentrations of 4, 5, 6.7, and 10 per cent, respectively. Applications made in July gave

almost as good a control as those made in June. Treatments made with a 10 per cent sulfamate solution in August or September gave a fairly good control but were less effective than those made in June or July.

With sodium chlorate, the average reduction of poison ivy from June applications was 35, 39, 38, and 79 per cent for the same respective solution concentrations. For treatments made with a 10 per cent chlorate solution in June, July, August, and September, the control was good, fair to poor, poor, and zero, respectively.

Very rarely was a complete kill of poison ivy obtained from a single application of either herbicide. Follow-up treatments in two or more years were required to eradicate the ivy. Eradication was achieved with less material and fewer treatments when the applications were made in June or early July. In the follow-up treatments, fewer applications were required with ammonium sulfamate than with sodium chlorate to give complete eradication.

After treatment with both herbicides, the poison ivy foliage turned brown and died within from 5 to 7 days. Some of the plants sprayed with sodium chlorate put forth new leaves within one month following treatment, but, on those treated with ammonium sulfamate, new growth did not appear until the following summer. On the sodium chlorate plots, the new growth arose from existing upright stems, while, on the ammonium sulfamate plots it came direct from underground rootstalks.

The most pronounced reduction of poison ivy was obtained under conditions of low rainfall.

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THE RELATIONSHIP OF CLEAN FLEECE WEIGHT TO FIBRE THICKNESS[1]

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INTRODUCTION

The production of a maximum amount of clean wool per sheep is of paramount importance as this is the basis on which gross returns are determined. Although wool growers usually receive a higher price per clean pound for fine wool than for the coarser grades, production of fine wool is not necessarily the most remunerative. Greater amounts of coarser wool per sheep at slightly lower prices may result in larger total returns.

While there are many factors involved in wool improvement the most vital to the producer are those directly associated with greater wool production per sheep. These can be summed up in the term clean fleece weight, which in turn is dependent upon grade (i.e. fibre thickness), length of staple, density of fibres on the skin, and body size. The present study was undertaken to determine the relationship of clean fleece weight to fibre thickness, to ascertain whether selection on this basis of fibre thickness would be effective in the improvement of clean fleece weights.

REVIEW OF LITERATURE

Relatively little information is available on the actual relationship of clean fleece weight to grade, i.e. fibre thickness. However, several investigators have reported data in an effort to ascertain its economic significance. Burns (1) found that the coarser fleeces studied at the University of Wyoming weighed heavier and produced more clean wool per sheep than the finer fleeces. The average clean fleece weight of mature range ewes was 3.7 pounds for fine staple while one-half blood and three-eighths blood staple were 4.4 and 5.5 pounds, respectively. In the case of rams the one-half blood fleeces averaged 5.2 pounds and the one-quarter blood 8.4 pounds of clean wool per head. Results obtained from an analysis of 3,482 fleeces by Pohle and Keller (4) indicated a similar situation. Clean fleece weights for mature ewes increased from 4.3 pounds for fine French combing through the various grades to 6.6 pounds for one-quarter blood staple. For yearling ewes the range was from 3.3 to 5.9 pounds for the same grades. Spencer, Hardy, and Brandon (5) concluded from a study of the wool production of range Rambouillet ewes that as the fibres became coarser there was a slight tendency for the clean fleece weights to increase. Their data showed that the clean wool per fleece increased from 3.0 to 4.4 pounds, the grades being 68's and 56's, respectively.

[1] Contribution from the Experimental Farms Service, Dominion Department of Agriculture, Ottawa, Canada. Part of a thesis submitted to the School of Graduate Study, University of Wyoming, Laramie Wyoming, in partial fulfilment of the requirements for Degree of Master of Science.

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MATERIALS AND METHODS

Clean Fleece Weights

In 1946, 809 individual grease fleece samples were collected from experimental flocks in Western Canada and the Central Experimental Farm, Ottawa. These wool samples were scoured and the yields ascertained (basis 16 per cent regain) in accordance with standard laboratory procedure (6) to determine the clean content of each fleece.

Fibre Thickness

Each scoured sample was zoned and a small random sub-sample drawn for fibre thickness measurement. A cross-section was prepared from this material by means of the Hardy Thin Cross-Section Device (2) and with the aid of a microprojector projected on to a frosted glass screen at a magnification of 500 × (3). Two hundred fibres per sample were then measured, using a bi-diameter scale.

RESULTS AND DISCUSSION

The average clean fleece weights by grades for the fleeces analysed in this study are summarized in Table 1.

TABLE 1.—AVERAGE CLEAN FLEECE WEIGHTS BY GRADES

Grade	Number of fleeces	Average clean fleece weights
Fine staple	461	3.9
One-half blood staple	192	4.5
Three-eighths blood staple	68	4.9
One-quarter blood stable	62	4.8
Low one-quarter blood staple	19	5.6
Common and braid	7	5.7

It is apparent from these data that there is a general relationship between average clean fleece weights and fibre thickness expressed as commercial grades. The average clean weights increased from 3.9 to 5.7 pounds from the finest to the coarsest grades or a difference of 1.8 pounds. These results are in general agreement with those obtained by Burns (1) and Pohle and Keller (4), and indicate that as fibre thickness increases clean fleece weight has a tendency to increase. However, this is a general relationship and presumably arises out of the fact that fibres tend to increase in length as they become coarser and in addition breed effects enter into the picture over the whole range of grades considered.

More important from the standpoint of the breeder of one breed of sheep is the question of whether the same relationship holds true within the breed where the range of fineness normally is not so great. To partially answer this question a further, more detailed analysis was made of the data. To eliminate the effect of location, management, feed, breed or cross, and sex differences the data were analysed for each group separately as shown in Table 2.

TABLE 2.—AVERAGE CLEAN FLEECE WEIGHTS, AVERAGE FIBRE THICKNESSES AND COEFFICIENTS OF CORRELATION BETWEEN CLEAN FLEECE WEIGHT AND FIBRE THICKNESS BY BREEDS AND CROSSES, SEX, AND AGE

Source, breed or cross, sex, and age[1]	Number of fleeces	Average fibre thickness	Average clean fleece weight	Coefficient of correlation	Probable error
		(microns)	(lb.)		
Dominion Experimental Station, Lethbridge					
Rambouillet rams	27	20.6	4.2	0.093	±0.129
Rambouillet ewes	88	20.2	3.7	0.054	±0.072
Can. Corr. rams	14	22.6	4.0	0.314	±0.162
Can. Corr. ewes	30	20.9	3.4	0.397*	±0.104
N.Z. Corr. rams	10	24.5	4.7	0.898**	±0.041
N.Z. Corr. ewes	8	23.4	4.0	0.170	±0.169
F1 ewes (N.Z.C. × Ramb.)	16	21.0	3.9	0.135	±0.166
C2 ewes (C.C. × F1)	5	20.2	4.0	−0.211	±0.107
C3 rams (C.C. × C2)	12	22.8	4.6	0.420	±0.160
C3 ewes (C.C. × C2)	41	21.2	3.9	0.163	±0.120
C4 rams (C.C. × C3)	9	23.6	4.2	0.716*	±0.110
C4 ewes (C.C. × C3)	17	22.6	4.0	0.301	±0.148
Dominion Range Experiment Station, Manyberries					
Romnelet rams	69	23.9	4.2	−0.071	±0.081
Romnelet rams (m)	12	27.5	5.5	−0.236	±0.184
Romnelet ewes	72	25.8	4.6	0.156	±0.078
Dominion Experimental Station, Swift Current					
Rambouillet rams	22	21.3	4.8	0.177	±0.139
Rambouillet ewes	37	21.5	6.2	0.446**	±0.089
Romeldale rams	19	26.1	4.4	0.100	±0.153
Romeldale rams (m)	4	27.5	7.3	0.871	±0.081
Romeldale ewes	18	25.0	5.8	0.399	±0.134
Central Experimental Farm, Ottawa					
Shropshire ewes (m)	26	31.1	4.4	0.429*	±0.108
Leic. × Shrop. ewes (m)	25	33.9	5.2	0.226	±0.128
Romnelet ewes	10	28.3	4.0	−0.052	±0.224
Romnelet ewes (m)	28	29.1	4.8	0.003	—
Can. Corr. ewes	10	24.7	3.9	0.050	±0.213
Can. Corr. ewes (m)	16	27.8	5.9	−0.105	±0.167
Leic. × Oxford ewes (m)	8	34.7	6.3	0.257	±0.223
Suffolk ewes (m)	5	34.8	4.8	−0.417	±0.250
Cheviot × Leic. ewes (m)	5	40.8	5.4	−0.117	±0.298
University of Saskatchewan, Saskatoon					
Rambouillet rams	51	20.6	3.5	−0.116	±0.093
Rambouillet ewes	92	21.1	3.2	0.084	±0.104

[1] The breeds and crosses are shearlings with the exception of those indicated as mature (m).
* Significant at 5 per cent level.
** Significant at 1 per cent level.

The results of this analysis indicate that within breed groups the relationship of clean fleece weight to fibre thickness does not hold true in all cases. There are only five significant coefficients of correlation, all positive, out of 31 calculated. Two are significant at the 1 per cent level and three at the 5 per cent level of probability. The presence of 26 non-significant coefficients, including eight that are negative, indicates the lack of a definite relationship within a breed.

The data that have been presented are in agreement with those of other workers to the extent that, when a large number of fleeces of various grades and from various breeds are considered, there is a relationship between

clean fleece weight and fibre thickness. As the fibres become coarser, fleece weights tend to increase. However, the data further show that this relationship is not sufficiently close within breeds to be of any practical significance in a selection program for improving fleece weights by selecting on the basis of fibre fineness.

SUMMARY AND CONCLUSIONS

Individual fleece samples were collected, analysed for average clean fleece weight and fibre thickness, and the degree of relationship between these two characteristics determined.

In the preliminary analysis the clean fleece weights were assembled by grades and it was found that as the wool became coarser there was a definite trend towards increased clean weights. However, when the coefficients of correlation between clean weight and fibre thickness were calculated to determine the actual degree of relationship within a grade or breed it was found that only in a few cases was there any relationship between these two characteristics. It may be concluded that the relationship is sufficiently slight to not be evident within narrow ranges of fibre thickness.

ACKNOWLEDGMENTS

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BOOK REVIEW

"Scientific Horticulture". Published for the Horticultural Education Association by Jarrold & Sons Ltd., The Empire Press, Norwich, England.

After a lapse of some years, *Scientific Horticulture* has again made its appearance. Volume IX, 1949, contains a number of interesting articles.

An article on Soil Organic Matter and Composts is of particular interest to all horticulturists. The recommendations on the use of sewage sludge for soil fertility purposes should receive more attention in Canada, as we lose a considerable source of fertility, and the more general adoption of this system would aid in preventing the pollution of streams. The use of such sludge composted with straw would be of considerable value to small holders. Other articles deal with rapid tissue tests for mineral nutrients in plants and plant injection methods used by investigators in diagnosing nutritional deficiencies.

There is also an interesting account of modern applications of genetics and cytology to horticultural crops, dealing with mutations, bud sports and chimaeras, which help to explain apparent inconsistencies in the breeding behaviour of certain plants.

The article dealing with selective weed control is valuable for the historical data presented and summarizes the situation at the present time as regards the use of selective weedicides.

Another article of particular interest to horticulturists deals with preparation of composts for flats in greenhouses, etc.; rather definite recommendations are given for the preparation of a suitable compost.

— M. B. DAVIS
Dominion Horticulturist

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AGRICULTURAL EDUCATION

1. A program for directed participating experience as a part of the preparation of teachers of vocational agriculture. State College, 1949. 28 p. (processed) (Pennsylvania state college. School of agriculture. Agricultural experiment station. Progress report no. 15)

AGRICULTURAL ENGINEERING

2. Grain drying with forced air circulation. E. A. Olson and others. Lincoln, 1949. 9 p. il. (Nebraska. University. College of agriculture. Extension circular 736)
3. Electric fence controllers. John E. Nicholas. State College, 1949. 19 p. figs. processed. (Pennsylvania state college. Agricultural experiment station. Progress report no. 14)
4. Adobe or sun-dried brick for farm buildings. T. A. H. Miller. Wash., 1949. 18 p. figs. (U.S. Department of agriculture. Farmers' bulletin no. 1720, revised)
5. Automatic poultry feeder plan. D. C. Sprague and others. State College, 1948. 5 p. il. (processed) (Pennsylvania state college. Agricultural experiment station. Progress report no. 2)
6. How to build a homemade wood stave silo. W. L. Griebeler and M. G. Huber. Corvallis, 1949. 11 p. figs. (processed) (Oregon state college. Extension service circular 529)
7. A new type of prefabricated building. Paul L. Erdner. (Agricultural engineering, vol. 30, no. 10, October, 1949. pp. 477-478)
8. The development of a farm crop drier. John Weaver and others. (Agricultural engineering, vol. 30, no. 10, October, 1949. pp. 475-76, 478, 488)

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9. Operational research in German agriculture. G. Preuschen. (Research; a journal of science and its applications, vol. 2, no. 10, October, 1949. pp. 455-458)
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11. A preliminary list of the endemic flowering plants of Florida. Pt. II. Roland M. Harper. (Quarterly journal of the Florida academy of science. Vol. II, June-September 1948 (1949), nos. 2-3. pp. 39-57)
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